REGIONAL CLIMATE, FEDERAL LAND MANAGEMENT,

AND THE SOCIAL-ECOLOGICAL RESILIENCE OF

SOUTHEASTERN ALASKA

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A

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Abstract

Complex systems of humans and nature often experience rapid and unpredictable change that results in undesirable outcomes for both ecosystems and society. In circumpolar regions, where multiple converging drivers of change are reshaping both human and natural communities, there is uncertainty about future dynamics and the capacity to sustain the important interactions of social-ecological systems in the face of rapid change. This research addresses this uncertainty in the region of Southeast Alaska, where lessons learned from other circumpolar regions may not be applicable because of unique social and ecological conditions. Southeast Alaska contains the most productive and diverse ecosystems at high latitudes and a human population almost entirely isolated and embedded in National Forest lands; these qualities underscore the importance of the region's climate and federal management systems, respectively. This research presents a series of case studies of the drivers, dynamics, and outcomes of change in regional climate and federal management, and theoretically grounds these studies to understand the regional resilience to change.

Climate change in Southeast Alaska is investigated with respect to impacts on temperate rainforest ecosystems. Findings suggest that warming is linked to emergence of declining cedar forests in the last century. Dynamics of federal management are investigated in several studies concerning the origins and outcomes of national conservation policy, the boom-bust history of the regional timber economy, and the factors contributing to the current "deadlock" in Tongass National Forest management. Synthesis of case study findings suggests both emergent phenomena (yellow-cedar decline) and cyclic dynamics (timber boom-bust) resulting from the convergence of ecological and social drivers of change. Adaptive responses to emergent opportunities appear constrained by inertia in management philosophies. Resilience to timber industry collapse has been variable at local scales, but overall the regional economy has experienced transition while retaining many of its key social-ecological interactions (e.g., subsistence and commercial uses of fish and wildlife). An integrated assessment of regional datasets suggests a high integrity of these interactions, but also identifies critical areas of emergent vulnerability. Overall findings are synthesized to provide policy and management recommendations for supporting regional resilience to future change.

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Preface

Format
This dissertation contains three manuscripts that either have been submitted or will soon be submitted to peer-reviewed journals. As a result, there is some repetition of information and maps among chapters. The cedar decline manuscript (Chapter 2) is currently being revised for resubmission to *Canadian Journal of Forest Research*. The ANILCA manuscript (Chapter 3) will be submitted to *Conservation Biology* after revisions are made based on friendly reviews. The manuscript integrated into Chapter 6 has been submitted to *Ecosystems*; the version herein has been revised to better fit the dissertation (and to mesh more smoothly with the chapter). Each of the above journals has different formatting requirements; citations are formatted in the standard method required by most scientific journals. Chapters 2, 3, and 5 are structured in a standard way (e.g., intro, methods, results, discussion). Chapters 1, 4, and 6 are structured differently according to the chapter's purpose; e.g., literature review, historical narrative, synthesis of findings (respectively). Throughout the dissertation, headings and subheadings have been structured to maximize the clarity and accessibility of the content herein.

Collaborators
This doctoral research reflects an extensive amount of collaboration with research scientists at both academic institutions and government agencies. In all cases, the initial research questions, resulting analyses, and conclusions drawn reflect my own original efforts. Considerable assistance in revising manuscripts that are contained in this dissertation (Chapters 2, 3, and 6) was provided by faculty advisors, agency collaborators, and several anonymous referees. Final revisions contained in this dissertation were completed entirely by the author.

Members of my UA-Fairbanks advisory committee, particularly Terry Chapin, Amy Lovecraft, and Glenn Juday, have been closely involved with various aspects of this research. Each of the above faculty members is a co-author on one or more of the manuscripts (prepared for journal submission) contained herein.

For the cedar research, I worked closely with faculty and students at the University of Alaska Fairbanks (Glenn Juday, PhD; and Scott Sink, M.Sc.) and the Juneau Forestry Sciences Laboratory of the USDA Forest Service Pacific Northwest Research Station (Paul Hennon, PhD; and David D'Amore, M.Sc.). Chapter 2 is a minimally revised version of the manuscript for which the above individuals are coauthors.

For management and ecosystem services research, I worked closely with Trista Patterson, PhD and Linda Kruger, PhD; both of whom are part of the Human and Natural Resources Interactions team at the Juneau Forestry Sciences Lab (USDA PNW). For the last two years, my office has resided at Juneau FSL, thanks to a cooperative volunteer arrangement with Linda Kruger and PNW. Trista Patterson is a co-author on the manuscript that has been integrated into Chapter 6.

Acknowledgements

Over the course of this research, I have been fortunate to collaborate with and learn from a great number of scholars, students, public officials and local residents. Without their insights and the fruits of their labors, this research, which has been only a part of my 'education' since arriving in Alaska five years ago, would not have been possible. In particular, I would like to acknowledge the following individuals for their exemplary contributions to this effort, and their friendship, guidance, and support:

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Chapter 1

Introduction: Southeast Alaska as a social-ecological system

1.1 Summary

The purpose of this introductory chapter is to provide an overview of the theoretical rationale and objectives of the dissertation. I describe the region of Southeast Alaska to familiarize readers with its natural features (e.g., geography, climate, ecology) and its social features (e.g., economy, management, policy) and their principal dynamics of change. Unlike many other high-latitude regions, there has been relatively little research addressing the regional implications of larger-scale drivers of change. Based on complex adaptive systems theory, I define the region as an integrated social-ecological system (SES) that is governed by internal processes, organizing components, and external drivers of change. I focused on two critical organizing components that have shaped the SES and its responses to change: the regional hypermaritime climate and Tongass National Forest management. I hypothesized that the regional climate and land management have responded to significant, transformative drivers of change at multiple scales and that these responses have shaped, and will continue to shape, the SE Alaska SES. To evaluate this broad hypothesis, I conducted three independent studies related to climate change (Chapter 2), federal land use policy in SE Alaska (Chapter 3), and Tongass resource management (Chapters 4 and 5). Key insights from these studies are synthesized in the concluding chapter (Chapter 6).

1.2 Introduction

The world is experiencing rapid drivers of environmental, economic and cultural change, including climate warming, population growth, globalization, and declines in biodiversity. We know that much of the recent environmental change, and its impacts on society, has been the result of human actions in the biosphere. From these waves of change, numerous crises and conflicts have emerged, often rapidly and without precedent. Among these are disease pandemics such as AIDS and influenza, collapses in fisheries and wildlife populations, and the degradation of ecosystems upon which humans are dependent. From the latter, emergence of conflicts and crises include the salinization of agricultural lands, eutrophication of lake habitats, and conversion of forests to grazing lands. Because humans tend to focus narrowly on desired outcomes in both ecosystems and social systems, 'surprises' occur that tend to result in undesirable outcomes for linked systems of humans and nature. Despite our disciplinary expertise, we usually cannot observe the mechanisms of crisis and collapse until well after they occur.

Circumpolar regions have experienced many converging drivers of change in the last century, including a warming climate, dramatic changes in indigenous cultures, the pervasive impacts of European settlement, ecological and economic outcomes of resource development, shifting policies/governance, and economic globalization. Like many circumpolar regions, the southeastern region of Alaska has experienced these multiple, converging drivers of change. The impacts of change are poorly understood in Southeast Alaska, in part because of the unique social and ecological conditions in the region.

High-latitude ecosystems of unrivaled productivity and diversity

Southeast Alaska is a landscape characterized by a strong maritime influence, a very wet and mild climate, island archipelagoes, steep coastal fjords and tidewater glaciers.

Comprising about 23 million acres of the ‘panhandle’ of Alaska, it is a geologically complex region with several major active faults and volcanoes. A prominent Pleistocene glacial influence is apparent throughout the region’s terrain and soils. The northern portions of the mainland remain heavily glaciated, including the southernmost tidewater glaciers in North America. High precipitation throughout the year supports coastal rainforest ecosystems and links the marine and terrestrial environments, by maintaining stream conditions for large populations of anadromous fish that spawn in most of the region's streams and rivers. Salmon (Oncorhynus spp.) are keystone species for both ecosystems and social systems in SE Alaska, and in many ways function to link human and natural communities in the region. The region contains the largest remaining pristine areas of the temperate rainforest, a globally rare ecosystem. Due mainly to the mild maritime climate, SE Alaska’s biological productivity and diversity are unsurpassed in continental (inland) climates at similar latitudes. For example, the average standing biomass of closed-canopy conifer forests in SE Alaska is nearly four times that of the most productive forests found in interior Alaska (Mead 1995; Mead 1998). In total, the productive terrestrial and marine habitats of SE Alaska provide either year-round or critical migratory habitat for many species threatened elsewhere in the world (e.g., brown bear, Steller’s sea lion, sea otter, American marten, marbled murrelet, bald eagle, and humpback whale).

Human communities exist as ‘islands in a sea’ of public land

Southeast Alaska is also a unique social landscape, because nearly all of its communities are isolated from the mainland road network and are located within the boundaries of the Tongass National Forest. Over 90% of land in SE Alaska is owned and managed by various local, state and federal government entities; the Tongass itself comprises about 80% of SE Alaska and is the largest US National Forest (Figure 1.1). Communities are basically embedded in a matrix of National Forest land, and nearly all land-use decisions involve the Tongass in some way. As a result, the Tongass exerts a large degree of influence on the patterns of settlement and resource use in the region. Most private lands are owned by various Alaska Native corporations under the Alaska Native Claims Settlement Act. The sparse regional population (73,000 residents; 2.1 people per square mile) is concentrated in two urban areas (Juneau and Ketchikan) and 32 rural communities and settlements, including eight Alaska Native villages. Government (federal, state, and local) is the single largest employer in the region, followed by the service sector (including seasonal tourism jobs), seafood processing, commercial fisheries and health care.

Drivers of change in Southeast Alaska

Like many high-latitude and/or resource-dependent regions, the ecological and human communities of SE Alaska have recently experienced rapid changes in climate, management, policy, and economy. Despite the growing emphasis on high-latitude change in research and policy, the origins and cumulative impacts of change in SE Alaska remain poorly understood (in both the ecological and human dimensions). In particular, climate and federal land management have shaped the region of SE Alaska in fundamental ways, and both have experienced strong drivers of change in the last century. This research is designed to improve understanding of change in SE Alaska.

Climate change has potentially wide-ranging implications for the structure and dynamics of the ecosystems of SE Alaska. A few of these impacts have already been observed, but remain poorly understood with respect to future trends (e.g., glacial retreat and coastal uplift); even more uncertain are the putative effects of climate change on the tight linkages between local economies and ecosystems in SE Alaska (e.g., subsistence, fisheries, tourism, timber, amenity migration). Anadromous fisheries, for example, are critical 'keystone' elements in the regional SES because they link marine and terrestrial ecosystems, which are linked with the social system in several ways (e.g., subsistence, commercial, and sport fishing). Although fisheries (and other resources) appear to be healthy in SE Alaska, we find that cases of fishery collapses and other resource crises can emerge rapidly without warning (Folke et al. 1991; Ludwig et al. 1993; Scheffer et al. 2001; Carpenter and Brock 2004) often in response to the interactions of global change and resource management (Light et al.

1995; Holling et al. 2002). In short, there is a large degree of uncertainty in SE Alaska with respect to climate change and its broader impacts. In the future, it will be necessary to closely monitor climate-related changes not only for local ecosystems, but also for the dynamic interactions among social and ecological systems.

The historical dynamics of federal land management in SE Alaska have affected local communities, especially those involved in the timber industry. The stability of Tongass policy and management over several decades afforded growth in the industry and its dependent communities (Rakestraw 1989). The recent decline of the timber industry concluded a forty-year period of intensive commercial logging on Tongass and Alaska Native lands, which supported several large mills and nearly 4,000 jobs (Soderberg and Durette 1988; Nie 2006). Similar to other timber-dependent regions in the U.S. Pacific Northwest, the collapse of the industry has fostered dramatic changes in several communities. Small settlements - many of them erstwhile logging camps - have been deserted in some cases, while others have transitioned towards ecotourism and related activities (e.g., the towns of Thorne Bay and Coffman Cove on Prince of Wales Island). Likewise, the larger timber-dependent communities of Wrangell, Sitka, and Ketchikan in recent years have embraced tourism and the service economy to varying degrees (Allen et al. 1998). One clear trend in nearly all SE Alaska communities is the increasing importance of the guide/outfitter industry, where the fastest growth has occurred in the small 'family-operated' businesses (Colt 2006). Meanwhile, as the regional economy transitions away from a dependence on resource-exploitive industry, the demographics of SE Alaska are also changing. The steadily increasing trend of amenity migration[1] means that a growing proportion of the population is composed of 'new' residents who rely largely on unearned income (e.g., pensions and retirement funds) and may hold considerably different values for local ecosystems and social institutions. Lastly, environmental policies - including those that have set aside large areas of the SE Alaska landscape from development

[1] Amenity migration can be defined as the in-migration of residents into a community or region for primarily non-economic reasons, such as scenery, isolation, recreational opportunities, etc.

(e.g., wilderness areas and parks) - have reshaped the current and future management options, as well as economic opportunities, in the region.

Overall, while several of the recent outcomes of management-related change have been documented in SE Alaska, there is a great deal of uncertainty about the broader-scale impacts of these changes on the linkages between human and natural communities in the region. These uncertainties include the impacts of economic transition and demographic shifts, the opportunity costs and tradeoffs associated with wilderness conservation, and the social and ecological legacies of the industrial timber era. Taken individually, these emergent issues warrant in-depth study; but perhaps more importantly, we must attempt to understand their origins if we are to understand their complex interactions in the future. If undesirable outcomes have emerged from past management and policy - as scholars, interest groups, and local stakeholders have suggested, although for widely disparate reasons - then it is necessary to understand how these outcomes came about, in order to prevent repeating the same mistakes in the future.

I suggest that while these drivers and outcomes of change remain largely unresolved and warrant in-depth study, they also provide a rare opportunity to observe the dynamics and resilience of a highly complex system of humans and nature. In other words, the importance of climate and management in SE Alaska make the region a valuable and interesting social-ecological 'laboratory.' In essence, we can observe how climate and management have changed during the 20th century, and the resulting outcomes for the region's human and natural systems, their dynamics (or patterns of change), and their most critical interactions (e.g., subsistence food harvest). Of course, in a region encompassing 23 million acres and 34 human communities, these systems and their interactions are extremely complex and occur at multiple scales. But because climate and management have been so influential in the region, the study of their dynamics is akin to manipulating key 'variables' in an experiment, and seeing how other 'variables' respond. In this way, I was able to focus in on some of the key drivers of change and their outcomes for SE Alaska during the 20th century. More broadly, I found this a valuable opportunity to describe how change occurs in complex systems of humans and nature.

1.3 Objectives

This research approached the study of SE Alaska with three questions in mind:

- How have climate and management responded to external drivers of change?

- How have these dynamics influenced human and natural communities of SE Alaska, and their interactions at local and regional scales?

- What has been the historical resilience of SE Alaska? How might vulnerability emerge in the future?

This introductory chapter serves two purposes: to ground the research in complex systems theory; and to provide an overview of the application of these questions through several case studies. To this end, I describe the systems approach used in this research and the rationale for its application to the study of SE Alaska. In other words, I justify the characterization of SE Alaska as a social-ecological system (SES), or a "linked system of humans and nature" (Walker et al. 2006). A highly simplified conceptual model of the SE Alaska SES is presented (mainly for illustrative purposes). In this chapter, I describe how this systems model framed the original research designed to investigate the dynamics of the SE Alaska SES at multiple scales. To familiarize the reader, the chapter includes a brief overview of key concepts in complex systems theory (e.g., non-linear dynamics, adaptive cycles, resilience, etc.) that are applied in the following chapters.

Because of the importance of climate and management in the region, I conducted several case studies to provide "windows" into the SE Alaska SES. The climate system is observed in a study of the widespread decline of Alaska yellow-cedar throughout the region. The management system is observed at several scales and over different time periods, including: a case study of how conservation policy came about in SE Alaska; a history of forest management in SE Alaska that highlights the origins and drivers of change associated with the boom and bust of the timber economy; and a case study of the current situation of Tongass management, focused on the factors that foster stability or drive adaptive change in planning for the future. Lastly, to begin to understand the legacy of land use change during the 20th century, I conducted an analysis of the integrity of ecosystem services and human uses that support local subsistence and commercial economies. These case studies and analyses provided an in-depth examination of system processes, drivers of change, and feedbacks across scales. In the final chapter, these studies are summarized to provide insight on the overall resilience of SE Alaska to historical patterns of change in climate and management during the 20th century.

1.4 Rationale and Theory

In recent decades, the emergence of numerous social and environmental crises has coincided with a period of rapid and sweeping change on a global scale (e.g., climate change, desertification of agricultural lands, deforestation, the AIDS epidemic). Many of these changes relate to the scale and intensity of human activities on the planet (Holling et al. 2002; Carpenter and Brock 2004). The anthropogenic modification and degradation of ecosystems, and the associated social consequences of ecological change, have been central themes in the crises, conflicts, and collapses of societies throughout history (Ehrlich and Mooney 1983; Redman 1999; Diamond 2005). The failures of traditional disciplinary approaches in observing the drivers of global change, understanding their significance at multiple scales, and reasonably predicting their outcomes are well documented (Berkes et al. 2003). In particular, the inability to account for emergent phenomena that arise from human-nature interactions at multiple scales has contributed to failures of resource management in many regions (Ludwig et al. 1993; Light et al. 1995; Gunderson and Holling 2002).

To understand these wide-ranging changes and their consequences, an integrative theory is needed. Such a theory must transcend boundaries of scale and discipline. It must also be capable of organizing our knowledge of ecological, economic and institutional systems, and describing situations in which these three types of systems interact (Holling et al. 2002). To this end, complex adaptive systems and resilience theory have emerged in recent years. Systems theory has become a valuable framework in both the natural and social sciences for understanding patterns of change, especially non-linear and complex types of change (Berkes et al. 2003). The complex systems approach has been emphasized in the study of linked dynamic systems of humans and nature, or social-ecological systems (Gunderson et al. 2002; Walker et al. 2006). The resilience of these systems, or their capacity to absorb change and retain their form and function, is critical to understanding their local and regional dynamics in response to global change.

1.4.1 Southeast Alaska as a social-ecological system

I defined the social-ecological system (SES) of Southeast Alaska as the region's human and natural systems and the complex linkages among them. More specifically, I refer to the SE Alaska SES as a multi-scale pattern of production and use of natural resources, around which humans have organized a particular social structure (e.g., communities, management institutions, consumption patterns, and associated laws, norms, and rules). This SES can be studied as a nested set of systems or "panarchy," whose system dynamics are coupled across scales through feedback relationships among systems (Gunderson et al. 2002, Holling et al. 2002, Davidson-Hunt and Berkes 2003). Although dynamics differ among scales, complex system behavior can be described by a small subset of system components and their dynamics across scales (Carpenter and Brock 2004; Walker et al. 2006).

To understand the broader dynamics of the SE Alaska SES, I developed a conceptual model of systems and 'nested' subsystems existing at different scales (Figure 1.2). At the largest scale, the SES includes all human and ecological communities, their interactions and their integrated dynamics. At this scale, for example, the regional SES is transitioning from a resource-based economy (e.g. timber, mining, fisheries) towards a service-based economy (e.g. tourism, recreation, amenity values). Within the regional SES, I defined two smaller-scale systems - regional climate and federal land management - as 'organizing components' that shape the configuration and dynamics of the SES.

I defined the 'regional climate system' to include historical and contemporary climate regimes of SE Alaska and their interactions with local ecosystems and human communities. My study of the climate system (Chapter 2) sought to establish a better understanding of local ecosystem responses to a changing regional climate. The 'federal land management system' focuses on the principal thrust of resource management in SE Alaska during the 20th century: a regional timber economy supplied by subsidized industrial forestry on public lands. The system includes the USFS-Tongass, the regional timber industry, timber-dependent communities, and the managed ecosystems impacted by timber harvesting activities. Nested within the management system there are two further subsystems: the 'policy subsystem' that governs Tongass management and land use decision-making and the 'economic subsystem' that defines the structure and capacity of the regional industry and the market demand/value of its timber exports. These subsystems are described in-depth in Chapters 4 and 5.

1.4.2 Alternative states and stability domains

Complex systems exist within a 'state space,' i.e., the n-dimensional space created by all possible combinations of the variables that define the system. At a given time and scale, we can observe the system 'state' as that unique combination of values of the defining variables. For example, a simple system defined by two variables can be visualized in a standard Cartesian two-dimensional space; of variables X and Y, any combination of (X,Y) is the system state. The dynamics of a system are defined by its shifts among states over time. Systems may exhibit stable and predictable, or chaotic and unpredictable dynamics, or both, depending on their complexity. A simple system of two variables behaves in a linear fashion, much like a regression model. By contrast, a complex system (defined by many interacting variables) tends to exhibit non-linear dynamics, meaning that state changes (or flips) occur rapidly and unpredictably. This type of behavior has been observed in ecological systems, policy systems, economic systems, and institutional systems (Holling et al. 2002; Baumgartner and Jones 1993; Repetto 1988).

State spaces often have one or more sets of conditions which draw the system towards a certain state, known as 'domains of attraction' or 'stability domains'. If we envision the simplified 'ball and cup' model (Figure 1.3) of system dynamics, we see that once the system (ball) enters a stability domain (cup), it requires a substantial perturbation to move away from the attractor (bottom of the cup). Thus the stability of the system is a function of the magnitude of the perturbation that causes a state transition. Transition among states can occur by forcing the system (internally or externally), or by changing the state space (to reduce existing attractors or create new attractors), or both. In general, the more complex a system is, the greater is the likelihood that stability domains exist in its state space (Gunderson et al. 2002;

Walker et al. 2006). Complexity may appear to foster greater stability; however, complex systems often experience dramatic state transitions, often for unknown reasons. Thus one of the broader goals of complex systems theory is to reveal why complex systems can appear to be stable, but behave chaotically.

1.4.3 Adaptive cycles and cross-scale feedbacks

Complex system dynamics over time tend to follow a pattern of growth, conservation, release (collapse) and renewal (reorganization) known as the adaptive cycle (Figure 1.4). The adaptive cycle concept has its origin in the general model that ecologists use to describe the process of forest succession; Holling (1986) took it further to describe any system where cyclic transition among states is observed. The following example uses Holling's definitions with reference to the forest succession metaphor. During the *growth* phase of forest succession, it rapidly accumulates capital (in the form of nutrients and biomass) that forms the structure (trees) and processes (photosynthesis and decomposition) that dictate the forest's state. As it matures over time, the structures (trees) and processes (competition) that retain this capital gradually become more interconnected and rigid in response to destabilizing factors (e.g., disturbance). During this *conservation* stage the forest can tolerate disturbances of a certain type and/or intensity (individual tree death) due to endogenous processes (gap replacement through advance regeneration). This period of growth and maintenance is the 'fore loop' of the adaptive cycle, which usually lasts a relatively long period of time. When disturbance (fire, disease, drought, etc.) exceeds the tolerance of existing structures (dominant trees, soils, etc.), the forest will experience a short period of rapid, non-linear change (tree mortality) in which the accumulated capital (nutrients and energy) is released. This *collapse* phase is followed by a period of *reorganization* in which remaining structures (surviving vegetation), novel elements (newly established plants), and local conditions (soils, climate, etc.) shape the process of renewal towards a new *growth* phase (regeneration of young forest). The *collapse* and *reorganization* phases form the 'back loop' of the cycle, which is characterized by rapid and dramatic change. During *reorganization*, the forest may regenerate into a similar state, or it may transition into a forest with a different structure or composition, or possibly a different type of vegetation community entirely (e.g., shrub woodland, grassland, herbaceous cover, or barren).

Many complex systems exhibit these sequential stages or some combination of them in a similar pattern of growth and release (Holling 1986; Gunderson et al. 1995, 2002; Walker et al. 2006). If complex systems must be observed at multiple scales to understand their dynamics (Berkes et al. 2003), the adaptive cycle provides a basis for observing scale-specific dynamics as well as cross-scale interactions (or feedbacks). As described above, just as smaller-scale systems can be 'nested' within larger-scale systems, we can observe 'nested' cycles at small scales driving the dynamics at large scales (Figure 1.5; Holling et al. 2002). In general, smaller-scale (or less complex) systems move rapidly through their adaptive cycles and generate feedbacks to larger (or more complex) systems that tend to move more slowly through the 'fore loop' (Gunderson et al. 2002).

Feedbacks to larger scale systems can be positive or negative. Positive feedbacks act to weaken existing structures and interactions, which tend to drive changes (e.g., *collapse* phase of the adaptive cycle). Conversely, negative feedbacks strengthen structures and interactions, which tends to prevent change; e.g., *conservation* phase). When 'nested' systems have cycles that coincide, their feedbacks can be magnified at larger scales, leading to "hypercoherence" (Walker et al. 2004). For example, the collapse of a larger-scale system can be driven by the cumulative feedbacks resulting from the hypercoherence of *collapse*-phase dynamics in two or more nested cycles. This phenomenon suggests that in certain cases, feedbacks may have a greater influence than the 'sum of their parts' (Holling et al. 2002; Walker et al. 2004).

In this sense, we can describe 'catastrophic' large-scale change in terms of smaller-scale dynamics and emergent phenomena, which may be more readily observable and thus more amenable to policy and management actions. Hence the utility of the complex systems approach; instead of attempting to measure or observe the SES in its totality, we can use smaller-scale systems as 'windows' onto the interactions that govern the overall SES dynamics. This principle, in conjunction with my knowledge of the region, guided my choice of systems and subsystems to study in the SE Alaska SES model (or panarchy; Figure 1.2). Climate and federal land management are arguably the most important 'organizing' systems in SE Alaska because of their historical and future roles in shaping the ecosystems and patterns of human resource use in the region, respectively.

1.4.4 Resilience and transformation

Resilience is the capacity of a system to absorb perturbations and reorganize under new conditions while still retaining essentially the same structures, internal controls and feedbacks (Walker et al. 2004). Perturbations may arise from the accumulation of smaller scale feedbacks or larger-scale (exogenous) drivers of change. As systems progress through the 'fore loop' (growth and conservation phases) of the adaptive cycle, resilience is thought to increase, level off, and eventually decline as stabilizing structures become rigid and/or maladaptive to changing internal and external conditions (Gunderson et al. 2002). When the system capacity to absorb change is exceeded, vulnerabilities emerge and transformation may occur - leading to the collapse phase of the adaptive cycle. Transformation of a system tends to change both the system state and its internal stabilizing processes. For example, in ecological systems, transformation often results in a structurally different and/or degraded ecosystem that is governed by unfamiliar processes (Holling et al. 2002). In policy systems, major reforms (transformations) are often accompanied by new rules and venues that make the decision-making process more complex and diffuse (Baumgartner and Jones 1993; True et al. 1999). In economic systems, boom-bust cycles often result in a broad restructuring of industry and social institutions, in which the new economy may be tied to different resources and markets (Gunderson et al. 1995; Berkes et al. 2003). Thus the concept of transformation serves to unify insights from several disciplinary perspectives in the pursuit of a broader understanding of complex SESs.

In most cases, the 'surprise' feedbacks of ecological degradation to society have driven SES transformation (Ludwig et al. 1993; Light et al. 1995; Redman 1999; Gunderson et al. 2002; Berkes et al. 2003), and in a few cases, societal collapse (Diamond 2005). By contrast, the resilience literature has not described many cases in which social feedbacks operated more strongly than ecological feedbacks. Given the largely pristine condition of the modern SE Alaska landscape, social forces of change may be relatively more significant in driving transformation in the SE Alaska SES. To address this question, it is necessary to identify transformative events and describe the systemic resilience to them. To this end, a number of questions arise. How has change occurred, and at what scale? What internal feedbacks and exogenous drivers were precursors of change? What new 'on-the-ground' conditions emerged as a result? How did the SES respond to these emergent phenomena and drivers of change? Lastly, was the SES able to reorganize under new conditions and maintain the same overall identity? If so, why was the SES resilient? These questions guided my selection of case studies and synthesis objectives in the study of SE Alaska.

1.5 Overview of research

I conducted three case studies that independently examined a different system within the SE Alaska SES, based on my systems model (Figure 1.1). Each case study (Chapters 2-5) was designed to observe the regional SES at different scales, and the synthesis of their findings (Chapter 6) integrated these observations at the SES scale.

Chapter 2 addresses the dynamics and feedbacks of the SE Alaska *climate system*, through a study of the relationship between climatic change and forest decline. Nearly one-half million acres of yellow-cedar (*Chamaecyparis nootkatensis*) forests in SE Alaska are experiencing a dramatic decline that appears to be associated with post-Little Ice Age climate change. However, the contemporary trends of regional change and their implications for forest ecosystems in SE Alaska remain largely unresolved; but see Viens (2001) for a historical perspective. The cedar study developed the first known regional-scale long-term weather record suitable for statistical analysis, as well as the first region-wide dendrochronology (tree-ring history) of a temperate rainforest tree species in Alaska. In the broader context of my dissertation objectives, the cedar decline study provided insights on regional vulnerability to global climate change.

Chapter 3 is a study of exogenous drivers of change and the *policy subsystem* of SE Alaska federal land management, as defined previously in this chapter (Figure 1.2). The disposition of 'national interest' lands in Alaska involved a long and contentious debate that found compromise in the passage of the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). Debate over the designation of protected areas (e.g., Wilderness, National Monuments) in the Tongass National Forest was especially intense. Alaska policymakers at local and national levels vehemently opposed the 'locking up' of lands and resources, as did the vast majority of their constituencies. However, a majority upwelling of national public opinion favored the conservation of Alaskan wilderness, especially in unique and biologically rich places like SE Alaska. For these reasons, the ANILCA case study provides a window into the dynamics of the policy subsystem in response to a largely exogenous driver of change (the environmental movement). The study integrates the findings of two disciplinary analyses: a policy analysis designed to understand how the policy subsystem resisted external change, and a gap analysis (from conservation science and landscape ecology disciplines) designed to understand the outcomes of the

ANILCA debate in the ecological and social landscapes of SE Alaska. I synthesized these findings to show how the SE Alaska policy subsystem shaped the designation of wilderness reserves in the Tongass, in terms of the biological and social importance of the resulting protected areas. Therefore, in the context of my broader objectives, Chapter 3 provides an example of how exogenous forces may drive cross-scale feedbacks that influence the larger-scale dynamics of the regional SES.

Chapters 4 and 5 examine the *federal land management system* at multiple scales to understand its dynamics in response to drivers of change during the twentieth century. These chapters address the boom-bust cycle of the SE Alaska timber economy and the rise and fall of the Tongass management regime that created and supplied the industry. I apply the adaptive cycle metaphor to frame the history of Tongass resource management in five phases: *organization*, *growth*, *conservation*, *collapse*, and *reorganization*. In a historical narrative (Chapter 4), I follow the progression of this cycle at multiple scales, including the 'nested' policy and economic subsystems of Tongass timber management (the primary thrust of federal land management in SE Alaska). Chapter 5 focuses on the current *reorganization* phase of the management cycle and how its current and future states are affected by the tension between forces of stability (inertia) and transformation (adaptation). In the broader context, Chapters 4 and 5 provide a window into the dynamic interactions across scales that drove change in federal management and, by proxy, the dynamics of the larger-scale SES.

Chapter 6 revisits these case studies and presents a new analysis to provide qualitative and quantitative measures of the resilience of the SE Alaska SES. Resilience is a function of system components, their dynamics, and their interactions at multiple scales (Gunderson and Holling 2002; Walker et al. 2004). In essence, the case studies examine SES components (climate, policy, and management systems) to observe their dynamics and resilience in response to multiple drivers of change. While their synthesis reveals several valuable insights on the SE Alaska SES, an understanding of regional resilience also requires knowledge of the functional interactions within the SES. These interactions, or processes, dictate the flows of energy, materials, and knowledge among human and natural systems at multiple scales (Low et al. 1999). Given the strong ties of SE Alaska residents and economies to the natural landscape, I focused on the flow of ecosystem goods and services as a critical process in the SE Alaska SES. To address SES *interactions* (or *processes*), I present an analysis of the production and use of ecosystem goods and services at a regional scale, with respect to the impacts of man-made disturbance regimes on these processes. I introduce a conceptual model and analytical framework for the evaluation of local vulnerability and regional resilience in this critical SES interaction. In the final section of Chapter 6, these results are integrated with case study findings in a discussion of the historical resilience of SE Alaska and its major drivers of change. I conclude with a perspective on the ongoing *reorganization* phase of federal management as a critical and immediate opportunity to build adaptive capacity and resilience for the future.

Figure 1.1. Map of Southeast Alaska landowners and communities.

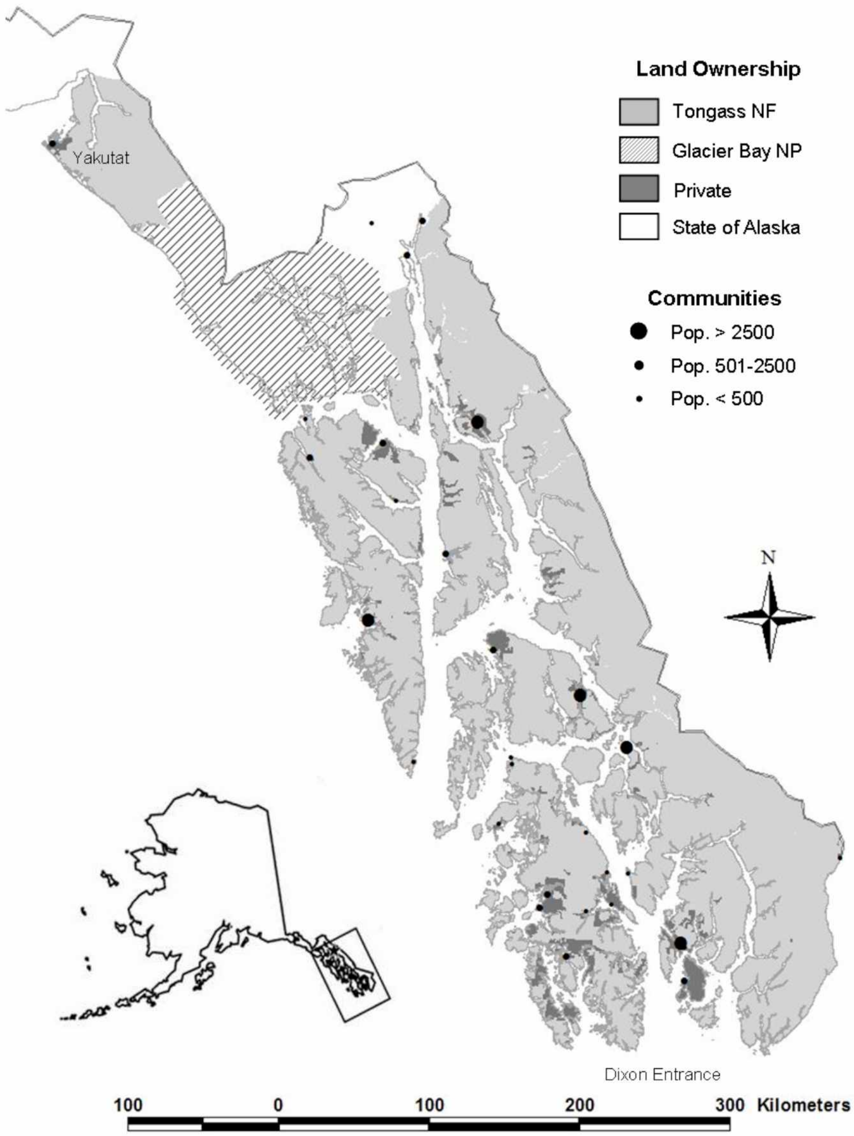


Figure 1.2. Conceptual model (or 'panarchy') of the social-ecological system (SES) of Southeast Alaska, as observed at multiple scales. System components and domains are described in the text (§1.4.1). Systems at smaller scales are 'nested' within larger scale systems when connected by a solid line.

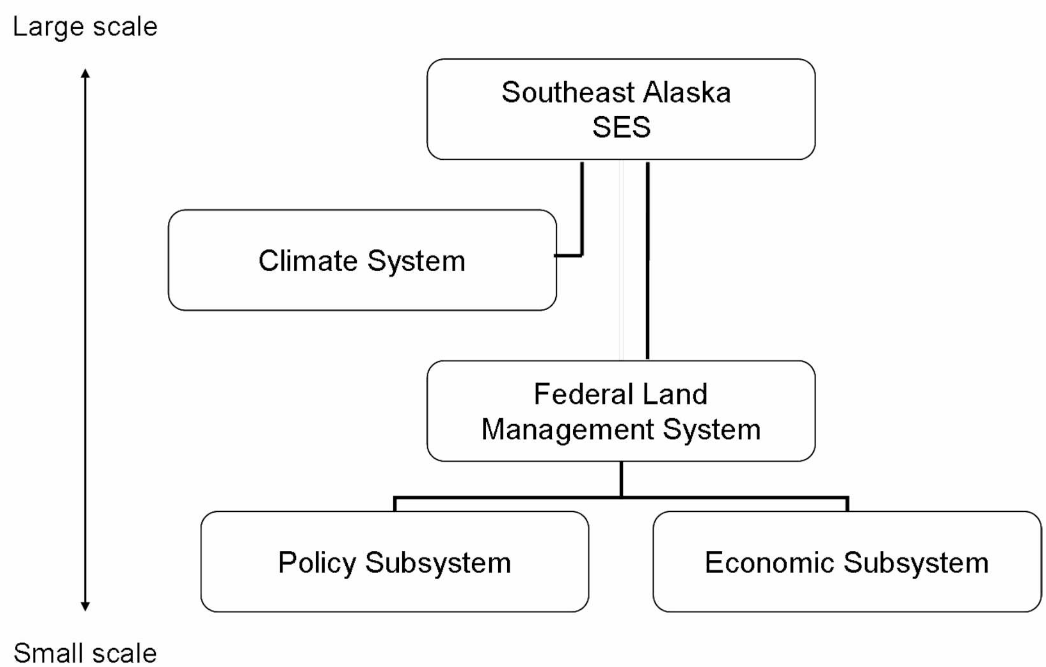


Figure 1.3. Ball and cup model of system state transitions and stability domains.

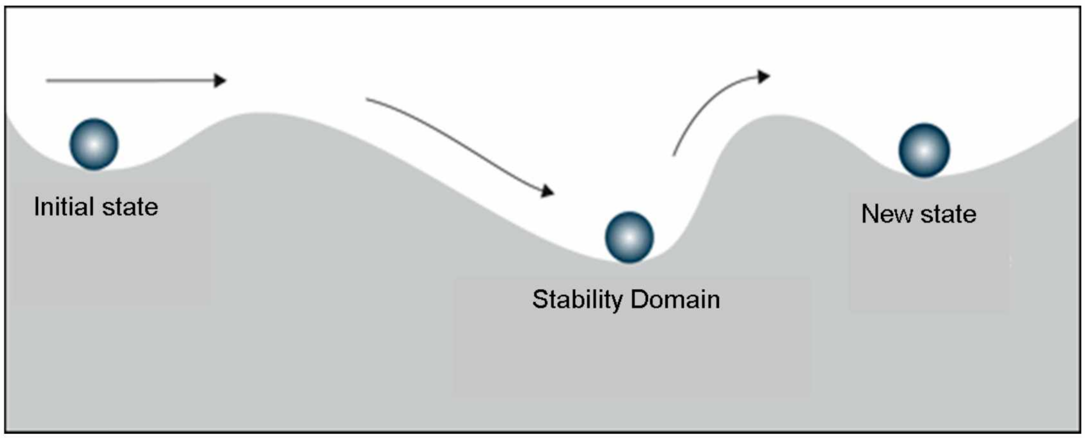


Figure 1.4. The adaptive cycle (from Holling et al. 2002).

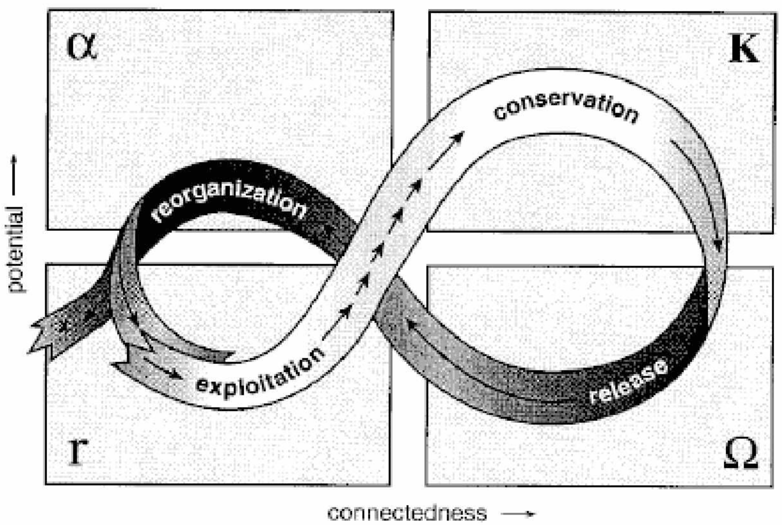


Figure 1.5. Nested adaptive cycles (from Holling et al. 2002).

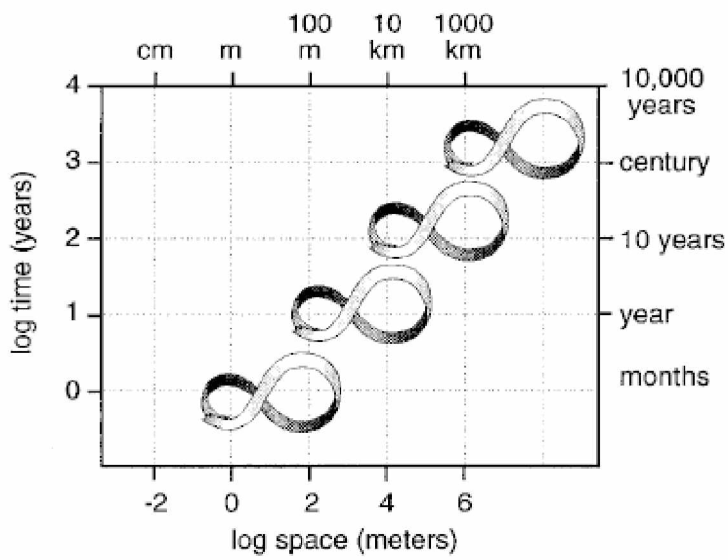
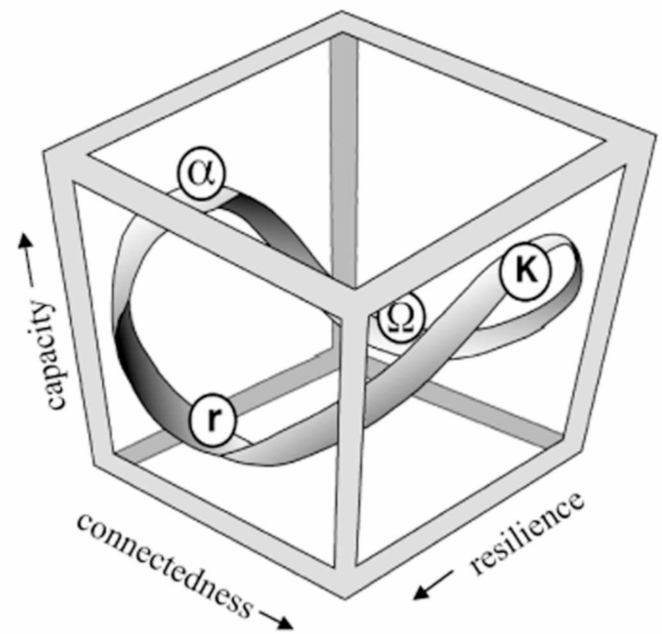


Figure 6. Resilience and the adaptive cycle (from Holling et al. 2002).



Chapter 2

Climate change and forest decline in Southeast Alaska

2.1 Summary

Decline of yellow-cedar (*Chamaecyparis nootkatensis*) has affected nearly 200,000 hectares of coastal temperate rainforest in southeastern Alaska. Cedar dieback has occurred almost exclusively in low-elevation populations that established during the Little Ice Age, a period of cooling that ended regionally circa 1880. Based on prior research, we hypothesized that yellow-cedar decline has occurred in response to post-Little Ice Age warming via a mechanism involving thaw-freeze cycles in late winter. Thaws in late winter may trigger premature dehardening and early growth, while removing the snow cover that insulates exposed soils from freezing. Under these conditions, yellow-cedar would be more vulnerable to early-spring frosts that are common in southeastern Alaska. Using regionally extensive tree-ring chronologies, we analyzed the 20th century growth responses of yellow-cedar populations to regional climatic variation and specific weather events. Our findings suggest that post-Little Ice Age warming is driving cedar decline through increased frequency of thaw-freeze events and reduced snowfall. Late winter weather was a consistently important regional factor in annual growth of cedar in declining populations. An increasing frequency of thaw-freeze events in the latter half of the 20th century corresponded with increased mortality of yellow-cedar. A severe thaw-freeze event during a low snowfall year in 1987 was reflected in the chronologies of declining cedar forests throughout the region. We propose that the decline phenomenon represents a climate-mediated 'retreat' of yellow-cedar populations that expanded into lower elevations during the Little Ice Age. Our findings, in conjunction with stand-level observations of cedar decline risk factors, support this hypothesis over a large spatial and temporal scale.

2.2 Introduction

The role of climatic regime shifts in the migration and extinction of plant species is well documented in the paleobotanical literature. Extinctions and range reductions occur when environmental change generates conditions that exceed a species tolerance. Tree populations tend to have long intergenerational lags, making it difficult to adapt to rapid environmental change, especially if the species is slow growing, long-lived and limited in its recruitment by low fecundity. Moreover, populations that established in marginal conditions during periods of favorable climate may be particularly vulnerable to rapid shifts in climate. In this paper we evaluate a climatic basis for the largest non-anthropogenic forest decline known in North America: the widespread mortality of yellow-cedar (*Chamaecyparis nootkatensis* ((D. Don) Spach) in the temperate rainforests of southeastern Alaska. Prior studies have shown that declining cedar forests have occurred almost entirely at low elevations (the species occupies a high-elevation habitat throughout its range) established during the Little Ice Age (Hennon and Shaw 1994; Wittwer et al. 2004). We hypothesized that subsequent warming has triggered cedar dieback through belowground freezing injury related to late winter thaw-freeze cycles and reduced insulating snow cover. We tested this hypothesis over large spatial and temporal scales by constructing tree-ring chronologies and regional climate histories, analyzing their trends and interactions, and coupling the landscape-scale approach with microclimatic and physiological observations from an intensively studied watershed (D'Amore and Hennon 2006).

2.2.1 Southeastern Alaska Climate and Ecology

The southeastern region of Alaska extends from Yakutat (59°N,140°W) to Dixon Entrance (55°N,130°W), including the western portions of the Coast Range on the mainland and the Alexander Archipelago. Modern climate is cryic and hypermaritime with abundant year-round precipitation, no prolonged dry periods, and comparatively milder seasonal conditions (e.g., cooler summers, warmer winters) than continental climates at similar latitudes. Mean annual rainfall averages about 2500 mm and ranges from about 1300 mm in the north (Haines) to nearly 4000 mm in the south (Ketchikan). Vegetation types include coastal spruce/hemlock forest, deciduous forest and shrubs, muskegs (peat bogs), and alpine dry tundra (Viereck and Little 1986). In general, forest productivity is governed by gradients in soil drainage dictated by slope, parent material, and peat accumulation. Along a productivity gradient, vegetation ranges from large-stature closed-canopy forests on well-drained soils to stunted open-canopy forest and shrub bogs (muskegs) on saturated peat soils (Neiland 1971). High rainfall supports a coastal rainforest dominated by western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and smaller amounts of mountain hemlock (*Tsuga mertensiana* (bonng.) Carr.), shore pine (*Pinus contorta* Dougl.), and two cedars, western redcedar (*Thuja plicata* Donn) and yellow-cedar. Mountain hemlock and yellow-cedar are abundant at treeline; yellow-cedar is also common on poorly-drained sites at low elevations, where the decline phenomenon is prevalent (Hennon et al. 1990).

2.2.2 Yellow-cedar decline

Yellow-cedar, also known as Alaska cedar or yellow-cypress, is a long-lived, slow-growing tree species of high commercial, cultural, and ecological importance in southeastern Alaska. The species has an extensive natural range from Prince William Sound in Alaska to northern California. Current populations in SE Alaska probably originated from early-Holocene northward establishment along the Pacific Northwest coast, as well as from smaller unglaciated refugia in the region (Carrarra et al. 2003). The cool-moist climate of the late Holocene (4,500 yrs BP) favored the establishment and expansion of yellow-cedar in SE Alaska, especially on sites with poor soil drainage due to organic matter accumulation (Hebda 1983). In the late Holocene (approximately 500 years BP), a period of cooling known as the "Little Ice Age" persisted in SE Alaska until approximately 1860-1880 (Heusser et al. 1985; Viens 2001). (Precise dates for the end of the Little Ice Age are uncertain; most scholars agree that a warming regime was in place by 1900.) In Alaska, yellow-cedar can be found from near timberline to sea level, while populations south of Alaska generally are limited to high elevations (Harris 1990).

Decline of yellow-cedar has been observed on nearly 200,000 ha in SE Alaska (Wittwer et al. 2004), almost entirely at elevations below 200m. Cedar dieback was first observed in SE Alaska in 1912 and has been recently found in the northernmost coastal forests of British Columbia (Hennon et al. 2005). A comprehensive body of research on the pathology of cedar decline has effectively ruled out biotic mechanisms (e.g., higher fungi, oomycetes, insects, nematodes, viruses and mycoplasmas, bears; see Hennon et al. 2006) and suggested an abiotic, climatic mechanism. Stand age studies suggest that currently declining yellow-cedar populations were established during the Little Ice Age, and that the onset of decline occurred between 1880-1900; coinciding with the end of the Little Ice Age in SE Alaska (Hennon et al. 1990; Viens 2001). Declining stands contain snags of various ages (time since death), with nearly all yellow-cedar trees dying within a 'decline zone' regardless of their age or size (Hennon and Shaw 1997). Most declining cedar stands are found in low elevation open-canopy forests on poorly drained soils, while cedar stands remain healthy on similar sites at higher elevations. Open canopy yellow-cedar forests experience greater extremes in diurnal variation of air/soil temperatures than closed-canopy forests (D'Amore and Hennon 2006). Snow cover effectively insulates open-canopy forest soils from temperature extremes, including hard freezes common in the late winter climate of SE Alaska (D'Amore and Hennon 2006). Relative to other endemic conifers, temperature appears to have a particularly strong influence on the dehardening processes for yellow-cedar, once a minimum photoperiod is reached (Puttonen and Arnott 1994; Hawkins et al. 2001). Thus the species may be prone to early dehardening when triggered by thaw conditions in late winter (Schaberg et al. 2005); and dehardened yellow-cedar may be especially vulnerable to soil freezing because of shallow rooting in saturated soils (Hennon and

Shaw 1997). Spring freezing injury to conifers tends to be more severe on warm slopes or at low elevations (Havranek and Tranquillini 1995); both factors are consistent with cedar decline, which is almost entirely found at low elevations, and more commonly on south and southwest-facing slopes (Wittwer et al. 2004). In sum, these observations have generated our model of yellow-cedar decline as a climate driven phenomenon (Figure 2.2.1).

2.3 Objectives

This study evaluates a potential climatic driver of yellow-cedar decline at large spatial and temporal scales using local weather records and an extensive regional tree ring sample. Our large scale analysis of tree rings is coupled with microclimatic observations at paired sites in an intensively studied watershed (D'Amore and Hennon 2006). We conducted a series of analyses designed to: a) understand the impacts of contemporary climate change on winter conditions; b) compare yellow-cedar growth chronologies among declining and healthy populations; c) describe the influence of late winter-early spring weather on cedar populations; d) generate climatic predictors of cedar growth; and e) identify thaw-freeze events and assess their likelihood as proximate stressors contributing to decline-related mortality.

2.4 Methods

Our approach tests the response of cedar populations to both proximate, short-term weather events and long-term warming trends as hypothetical drivers of the decline phenomenon. We also required a baseline understanding of the overall climatic predictors of cedar growth throughout the year, beyond the seasonal focus of our hypothetical mechanism (February-April). We therefore used two sets of yellow-cedar ring width indices (RWI) derived from the same raw data; the first RWI dataset was minimally detrended (only negative exponential trends removed), while the second RWI values were 'smoothed' using cubic spline detrending (to reduce variance and improve consistency of the climate signal) hereafter referred to as "raw RWI" and "smoothed RWI", respectively. Proximate weather influences – such as thaw-freeze events – were analyzed with the raw RWI; this dataset preserves any extreme outliers (marker years) that are the best indicators in a tree-ring record of population-level responses to proximate stressors. By contrast, to assess baseline influences of climate on cedar populations, we used smoothed RWI in our multivariate modeling of the climatic predictors of yellow-cedar growth. By reducing short-term variance through detrending, we could infer climatic influences in the absence of proximate, stochastic events that cause dramatic deviations from mean growth rates.

2.4.1 Climate data preparation and analysis

Historical climate records used in this study included daily minimum and maximum temperature, daily precipitation and snowfall for eight primary weather stations. All weather stations are located at or near sea level, and several have semi-continuous records dating back to the early 1900s (earliest records begin in 1848 in Sitka). Gaps occur in the data, ranging from several days to years in length, and weather stations have seen minor changes in location and data collection methods since installation. Mean daily (MDT) and monthly temperature (MMT) were compiled from daily min/max records; MMT values were not calculated from daily data if the monthly record contained a gap of more than three consecutive or five days total. To fill in missing MMT values, we interpolated an estimate based on the closest available station (Juday 1984). To improve the time span of continuous records in the Sitka and Ketchikan areas, we merged data from two pairs of stations in close proximity. Overlapping data were averaged for daily values during the period of concurrent measurement and used to interpolate values during gaps in the record at each station.

Daily mean temperature was used to compile growing days (MDT $\geq$ 5C) and freezing days (MDT $\leq$ 0C) for the months of February, March and April, for five localities

(Ketchikan-Annette, Sitka, Petersburg, Wrangell and Little Port Walter). For thaw-freeze events, we postulated that at least seven growing days were required for dehardening followed by at least two freezing days. We selected these parameters for thaw-freeze duration based on a review of pertinent literature (e.g., Sperry and Sullivan 1992; Puttonen and Arnott 1994; Auclair et al. 1996; Hawkins et al. 2001; Bourque et al. 2005), however, this criterion was speculative and designed to be conservative, identifying only the most severe and significant events. An algorithm was applied to the daily temperature records that selected all years where these conditions occurred during February-April for five localities back to 1900, or for the length of the record (if less). We did not account for elevation or topographical influences on air temperature that would be relevant at the stand level. Similarly, in the complex, highly dissected mountainous terrain of SE Alaska, rain and snow deposition varies greatly with landscape position, elevation and atmospheric circulation patterns. Since we lacked the capacity to describe historical snow cover conditions at a fine scale, we aggregated local weather data into regional indices of annual snowfall (October-April) and late winter rainfall (January-April) from 1950-2004. Precipitation data were very patchy and unreliable prior to 1950, the approximate date at which these stations first met First Order Weather Station standards. Linear regression modeling was used to identify significant trends in February-April MMT, annual snowfall and January-April rainfall.

2.4.2 Tree ring series and standardized chronologies

We identified the primary areas where sampling would occur by developing a GIS map of observed cedar decline and the existing road network. Most of our sites were below 200m elevation and within 5km of a road; we did not sample within 200m of the road corridor, downhill of clearcuts or within 100m of clearcut edges. We attempted a wide geographical dispersion of sites; however, most of our sites can be clustered into three regions: Peril Strait/Sitka, Central Islands and Prince of Wales Island (Table 1; Figure 2.2). In the Peril Strait area we sampled two stands in the same watershed (Poison Cove): a low-elevation declining stand and a high-elevation healthy stand (approximately 30m and 200m above sea level, respectively). Sampling of tree rings in this 'paired site' design allowed us to incorporate observations of air/soil microclimate, hydrology, and snow cover at these sites (D'Amore and Hennon 2006). Our regionally extensive sample focused on declining populations and only two healthy populations were sampled, at Poison Cove Bog and Juneau. The Juneau site was the only population located outside of the observed range of cedar decline (where low-elevation yellow-cedar is rarely found but is healthy). The healthy population at Poison Cove Bog was the high elevation stand in our paired site design. Increment coring was conducted at breast height on a minimum of fifteen live yellow-cedar trees chosen haphazardly at each site. We obtained at least two ring series per tree, either by coring completely through the bole (from the bark through pith to bark opposite) or with multiple single (bark to pith) radial cores. Ring series were visually cross-dated with a dissecting microscope and measured to 0.001mm resolution using a Velmex sliding stage apparatus.

Analysis of tree ring data requires several preliminary steps: cross-dating, detrending (standardization) and normalization. The COFECHA software application was used to detect potential cross-dating errors in ring series (Holmes 1983). Dating errors were corrected, and series with apparent missing rings were excluded from the analysis; of the 312 trees sampled, 254 were used (81.4%). For all trees with two or more accurately cross-dated ring series, we used the mean width of each annual ring in the analysis. Ring series were detrended and converted into standard chronologies using ARSTAN software (Cook and Krusic 2005). We used the interactive detrending option of ARSTAN to examine each tree ring series and determine if detrending was needed. The most common detrending option applied in tree ring studies is the negative exponential function; this accounts for the geometric bias in radial growth of the bole. To generate the raw RWI dataset, we took a conservative approach and only detrended those series which clearly required this step (< 5%). For the smoothed RWI dataset we used the same detrending as the raw RWI, then applied a 50 year cubic spline in ARSTAN. Tree ring series for each individual were aggregated into site mean chronologies and normalized using the subtraction method ((OBS-MEAN)/STDEV) for two time periods: 1800-2004 and 1900-2004. Normalized site mean RWI were then aggregated by regions: North Prince of Wales, South Prince of Wales, Mitkof, Kupreanof, Wrangell, Peril Strait, Sitka, and Juneau (Table 1).

2.4.3 Climate-growth analyses

The influence of regional climatic conditions on yellow-cedar growth chronologies during the 20th century was evaluated through several analyses. First, multivariate models were used to identify baseline climate influences; that is, the most common monthly climatic indices of temperature and precipitation influential in historical cedar growth patterns. These models provided the necessary context for analysis of the proximate climatic stressors in our hypothesis, by identifying the limiting factors that annual growing conditions impart on yellow-cedar populations. We used a stepwise regression procedure with mean monthly temperature (MMT) and precipitation (MMPPT) indices as explanatory variables and yellow-cedar regional RWI values as the response variable. The range of MMT and MMPPT indices included a twelve month period from September (t) to the September of the previous year (t-1). The stepwise procedure entered significant variables into the model at the $p < 0.1$ level. Parameter estimates and significance of explanatory variables were compared across models to determine the monthly climate indices that were the most consistent factors in cedar growth at the landscape scale. Each regional chronology was analyzed twice, using the raw RWI and smoothed RWI, to gain qualitative insight on the relative importance of proximate stressors (i.e. thaw-freeze events) in the climate-growth interactions of yellow-cedar.

To focus on late winter weather as a potential source of proximate stress to yellow-cedar populations, we analyzed growth responses to temperature indices and thaw-freeze events during February-April. Cedar growth responses to growing days (MDT ≥ 5C) and freezing days (MDT ≤ 0C) in February-April were inferred from correlation analysis. Raw RWI data were used in this analysis in order to maximize the sensitivity of results to sharp declines in the growth chronologies, since these 'marker years' suggest a population-level response to a major stressor. The significance of thaw-freeze events as a proximate stressor was evaluated in several steps. First, we identified those events that occurred regionally (at two or more weather stations) versus those that occurred locally (at one weather station). We cross-referenced winter snowfall data with regional thaw-freeze events (for 1950-2004) to identify the regional frosts that coincided with low snowfall years. Lastly we plotted the years where thaw-freeze events were observed and qualitatively compared these with common stress periods found in the regional chronologies.

2.4.4 Analysis of growth patterns at multiple scales

Regional chronologies were compared in correlation matrices to determine the presence (and strength) of common growth patterns among declining and healthy populations. We stratified this analysis by century, allowing comparison of growth patterns during the Little Ice Age (prior to the onset of decline) and post-Little Ice Age (during the decline phenomenon). For the paired sites in the Poison Cove watershed, we used correlation analysis to evaluate the similarity of growth patterns, also stratified by century. We intended that analysis of paired sites at Poison Cove would provide a 'space for time' model (or chronosequence), in which the contemporary high elevation healthy forest was analogous to the low elevation forest during the Little Ice Age.

2.5 Results

2.5.1 Overview of key findings

Our results provide several lines of evidence that climate change since the end of the Little Ice Age has driven the decline of low elevation yellow-cedar forests in SE Alaska. First, climate trends relevant to late winter-early spring conditions show this seasonal transition period (February – April) has become warmer and wetter since 1900. Winter snowfall (at sea level) since 1950 has trended downward while winter rainfall has increased during the same period; suggesting that an increasing proportion of winter precipitation is occurring as rain instead of snow at low elevations. Thaw-freeze events at the local and regional scale are becoming more frequent; for example, four of the five regionally significant events we found in the 20th century occurred after 1977. These trends suggest a significant distinction between contemporary and Little Ice Age winter conditions, especially at elevations near sea level where thawing temperatures are likely occurring earlier in the latter half of winter. Nearly all yellow-cedar trees in the sample populations were established during the Little Ice Age (prior to 1880), with a majority dating back at least to the 1700s. We found a common growth signal among declining populations across a wide geographical range. The healthy population in Juneau, found outside of the extent of observed cedar decline, did not share this common growth signal. Moreover, yellow-cedar responses to February-April temperature indices differed between healthy and declining populations. Lastly, the comparison of healthy and declining stands within the same watershed supported our model of how yellow-cedar decline could have begun with post-Little Ice Age changes in snow cover and soil microclimate. In the discussion, we apply this model in building a scenario of yellow-cedar mortality involving a major regional thaw-freeze event in 1987.

2.5.2 Trends in late winter climate

Regional weather records demonstrate that late winter climate has been warming in SE Alaska, with more precipitation falling as rain instead of snow, especially at low elevations (Figure 2.3a, 3b). Based on sea level measurements, annual snowfall has declined continuously since 1950, while December – April rainfall has increased during the 20th century. Late winter (Feb-Apr) mean monthly temperatures have increased according to regression models based on Ketchikan-Annette weather records from 1910-2004 (Figure 2.3c, 3d). Weather records from other locales in SE Alaska show trends similar to those at Ketchikan-Annette. Thaw-freeze events appeared to be more common in the latter half of the 20th century; this trend was largely due to warming February temperatures, not the frequency or severity of early spring freezes. We found a significant positive trend in February growing days (r^2=0.13, $p < 0.0005$), yet no trends in February or March freezing days during the same period. From 1900-2004, we identified 21 years in which thaw-freeze events met our stress criterion in the available weather records (at least seven growing days preceding three freezing days). Of these only five were 'regional', or verified at more than two weather stations (Table 2). We found that 1987 was the only year in which a regional thaw-freeze event occurred in all weather records; it was also the only regional thaw-freeze year in which regional snowfall was low (below one standard deviation of the 54 year mean). Weather records in 1987 indicated that a warm, rainy February was followed by a 7-10 day hard freeze in late February-early March (Figure 2.4).

2.5.3 Yellow-cedar population structure and growth chronologies

Prior studies on yellow-cedar decline suggested that low-elevation cedar stands were established earlier than 1900 (Hennon and Shaw 1994). Our results verify, at an extensive regional scale, that declining yellow-cedar populations were established at low elevation sites in SE Alaska during the Little Ice Age. Nearly all trees sampled were established prior to 1880; the estimated mean age of the sample population was 236 years (1768-2004). This is certainly a low estimate of average tree age, because in many cases, accurate cross-dating was not possible for many cores prior to 1700 due to missing and extremely narrow rings. We also cored snags in several sites which were impossible to accurately cross-date (due to decay), but which typically had several hundred growth rings. Very few sampled trees had rings prior to 1400.

Overall growth and interannual variability has trended upward for declining, low elevation yellow-cedar since the end of the Little Ice Age. In other words, surviving trees in declining forest have produced generally larger, but highly variable, rings since the onset of decline. When 1800-2004 normalized chronologies were partitioned by century, we found that mean variance was always significantly higher during the 20th century (two sided F-test, $p < 0.0001$). The same was observed for the healthy Juneau population, despite the decreasing trend in growth apparent in Juneau during the 20th century. At the regional scale, declining yellow-cedar populations shared a common growth signal from 1900-2004 (Table 3), based on correlation analysis of aggregated mean chronologies. This consistency in chronologies among populations indicates the importance of regional climate in low elevation yellow-cedar growth across SE Alaska. Marker years of exceptionally low growth, indicating stress beyond poor growing conditions, were found in nearly all tree-ring series for 1936, 1958 and 1987 (Figure 2.5a). Healthy sites (Juneau, Poison Cove Bog) had chronologies that were positively correlated with one another during 1900-2004, but unrelated in the previous century. Annual growth of the Juneau population was unrelated or negatively correlated with declining populations (Table 3).

2.5.4 Climatic influences on cedar growth

Early winter (October-December) and early spring (March-April) climate have the strongest landscape-scale influences on cedar growth at low elevations. Model components (climatic predictors) were broadly similar in runs using raw RWI and smoothed RWI, although with some notable differences (Table 4). Similar components and effects included: April temperature (positive effect), April precipitation (negative), January temperature (negative), October precipitation (negative), November precipitation (negative), and December precipitation (positive). Overall, the smoothed RWI models suggest a greater importance of early winter climate, while the raw RWI models suggest early spring. In other words, smoothed chronologies responded more strongly to the end of the growing season, while chronologies sensitive to stochastic, proximate disturbances responded more strongly to the start of the growing season. Climate vs. growth models for healthy populations were too weakly explanatory for inferential purposes, yet model components and effects differed dramatically between healthy and declining populations. Likewise, we found that healthy and declining populations responded differently to February-April temperature, based on correlation analysis of annual growth with cumulative growing days (MDT $\geq$ 5C) and freezing days (MDT $\leq$ 0C). Declining populations responded positively to growing days, while healthy populations responded negatively. Conversely, declining populations responded negatively to freezing days (strongest correlations with March) while healthy populations responded positively.

2.5.5 Comparison of healthy and declining populations

Analysis of paired sites in the Poison Cove watershed suggested that growth trends diverged during the 20th century between healthy and declining stands. During the 19th century, annual growth of the low elevation and high elevation cedar populations in the Poison Cove watershed was highly correlated (Figure 2.6a); indicating a common yellow-cedar growth signal within the watershed. This relationship was much weaker for the 20th century (Figure 2.6b) suggesting that this common growth signal deteriorated as the low elevation forest suffered decline-related mortality, while the high elevation forest remained healthy. Further, the climate-growth relationships for the two sites differed in the 20th century, as we discussed in the previous section. Our models indicated importance of spring climate at low elevations and the importance of early winter and late summer climate at high elevations. However, both chronologies contained similar marker years that suggest parallel responses to proximate stressors (Figure 2.6c). While the high elevation chronology appeared to be more sensitive to these stressors, we believe this is largely an artifact of higher overall variance due to smaller sample size. Our final sample for the healthy site (Poison Cove Bog) represented only twelve trees (n=12), less than one-fourth the decline site sample (n=51). The significance of these stress responses in the healthy population is addressed in the discussion.

2.6 Discussion

Our results describe climatic change as a driver of reduction in a species range, through decline of a population established during prior climate regime. Declining low elevation yellow-cedar forests in SE Alaska established during the Little Ice Age, under climatic conditions that today are more characteristic of higher-elevation habitats where yellow-cedar occurs throughout its range; a cooler regime with infrequent early thaws, greater snowfall, and more persistent snow cover into the growing season. Temperature records at Sitka dating back to 1848 – although patchy and marginally reliable prior to 1890 – suggest that late winter thaws were rare during the last decades of the Little Ice Age. Weather records in SE Alaska showed declining snowfall and warming late winter average temperatures since the end of the Little Ice Age. Despite the occurrence of warm periods in late winter, the eventual shifts to an atmospheric high pressure system bring cold arctic air from the mainland that can result in hard freezes persisting for a week or more. Based on our analysis of local weather records, these thaw-freeze events have increased in frequency during the 20th century. Sub-arctic warming is probably driving this trend, since thaw conditions (in February) became more common as the 20th century progressed, while freezes (usually in March) occurred with similar frequency throughout the century. Late winter thaws accelerate snowmelt and may also initiate dehardening in yellow-cedar, which is dependent primarily on temperature for its spring phenology (Puttonen and Arnott 1994; Hawkins et al. 2001).

The temperature-dependent spring physiology of yellow-cedar may explain why sympatric species are not experiencing similar decline in response to regional climate change (Silim and Lavender 1994). Recent testing has shown that between winter and spring measurements, yellow-cedar dehardens up to 13°C more than the sympatric Western hemlock, making it far more vulnerable to freezing injury in the late winter (Schaberg et al. 2005). Because it exhibits indeterminate growth, yellow-cedar is capable of shoot elongation prior to the budbreak of competing species (Puttonen and Arnott 1994). This adaptation likely provided a competitive advantage during the Little Ice Age, allowing this slow-growing species to proliferate in saturated lowland soils and compete with faster-growing Sitka spruce and Western hemlock on better drained upland soils. With a shift to a warming climate, we contend this trait has become a vulnerability for yellow-cedar at low elevation, where insulating snow cover may be absent in late winter. In sum, for modern yellow-cedar populations at the low elevation sites, the risk of freezing injury now outweighs the potential benefits of precocious growth. If warming trends continue, decline could extend to higher-elevation populations; in fact, expansion of decline zones from low-lying areas into upland forest has recently been observed (Hennon and Shaw 1997).

The region-wide thaw-freeze event in 1987 best illustrated our hypothetical conditions of proximate stress to low elevation yellow-cedar. Local thaw-freeze events also occurred during a common regional stress period culminating in the 1958 marker year (Figure 2.5b). Late winter conditions in 1987 present a scenario in which low elevation yellow-cedar forests were highly susceptible to thaw-freeze stress: a prolonged February thaw triggered dehardening in low elevation cedar stands across the region; snowpack in low elevation forests was low, due to below average regional snowfall during the 1986-87 winter. Warm ambient temperatures in conjunction with above average rainfall melted the insulating snow cover on exposed, low elevation soils. In late February, a hard freeze persisted for 7-10 days across the region, freezing the upper horizons of exposed soils and injuring the shallow root systems of yellow-cedar. This likely resulted in extensive fine root mortality that either stunted growth for surviving trees or lead to crown death and rapid senescence. A similar scenario occurred in 1986, with a regional, but less severe thaw-freeze event during a low snowfall year (that did not meet our initial criteria because the thaw lasted only five days). Based on tree rings, 1986 and 1987 were marker years for declining populations (in all chronologies and nearly all ring series). Age class estimates of cedar snags in these forests verified that a pulse of mortality occurred at approximately this time (Hennon et al. 1990). All decline chronologies increased sharply after 1987; an indication that surviving trees may have benefited from competitive release within the stand.

Yellow-cedar is healthy in the high elevation habitat common throughout its range, whereas the decline condition is found almost entirely at low elevations in SE Alaska and northern British Columbia. We observed that thaw-freeze stress may still be stunting growth in 'healthy' high elevation populations but is not coincident with decline. For example, the high elevation stand at Poison Cove responded with similar sensitivity to the 1987 thaw-freeze as the low elevation declining stand, yet the high elevation stand has not suffered from decline symptoms or extensive mortality. One explanation for this observation is a difference in cold-hardiness; in the Poison Cove watershed, trees growing below 130m were less hardy than those growing above 130m (Schaberg et al. 2005). Another explanation is that insulating snow cover is the key factor; compared to sites near sea level, yellow-cedar growing at higher elevations probably benefits from greater snow accumulation and longer persistence of snow cover into the growing season (D'Amore and Hennon 2006). There is a high spatial correlation of declining cedar populations in SE Alaska and low snowfall areas at the landscape scale, based on a snow accumulation model classified into low, moderate, high and very high zones (Figure 2.7). While thaw-freeze cycles can damage aboveground tissues regardless of snow cover, the pathology of cedar decline suggests a belowground injury (Hennon et al. 1990). Thus with adequate snow cover that persists beyond a period where yellow-cedar is vulnerable, high elevation populations can survive thaw-freeze cycles that are deleterious at lower elevations.

In several ways, our findings suggest that yellow-cedar decline in SE Alaska mirrors the decline of yellow birch (*Betula alleghaniensis* Britt.) in northeastern North America. Winter thaws followed by prolonged freezing events have long been recognized as a proximate stressor in northern hardwood forests of the eastern United States and Canada (Auclair et al. 1996; Auclair et al. 1997). Like our model for yellow-cedar, yellow birch: 1) is limited to high elevations in the southern areas of its range, 2) has declining populations in the northern areas of its range, with similar symptoms involving crown death and root necrosis, 3) has a tendency for early dehardening in which roots are active prior to shoots and foliage, and 4) is susceptible to root freezing during thaw-freeze cycles, especially when insulating snow cover is absent (Bourque et al. 2005). Thaw-freeze cycles have been linked with xylem cavitation, freezing of dehardened shallow roots, and shoot dieback in yellow birch; all are proximate factors in the decline of the species (Zhu et al. 2001, Zhu et al. 2002). A spatial interpolation analysis of thaw-freeze cycles showed that this stressor accounted for 83% of the spatial extent of observed birch decline (Bourque et al. 2005). Although our understanding of yellow-cedar stress physiology is still in its early stages, ongoing freeze tolerance research suggests that the shallow root systems of yellow-cedar are susceptible to thaw-freeze cycles much like yellow-birch (Schaberg et al. 2005).

2.7 Conclusions

From the tree to the landscape scale, several lines of evidence support the hypothesis that yellow-cedar decline has been driven by climatic changes since the Little Ice Age. The species' adaptation for temperature-dependent early growth likely provided a competitive advantage during the Little Ice Age but has become a vulnerability in low elevation stands. Yellow-cedar populations at low elevations may be especially vulnerable to freezing due to shallow rooting and rapid dehardening. We showed that during the 20th century winter weather in SE Alaska has become warmer and wetter in the late winter and early spring, with an increasing likelihood of potentially hazardous thaw-freeze events. Declining cedar populations displayed a common climatic signal at a landscape scale that exhibited common stress periods and about twice the interannual variation since the onset of decline. Tree ring chronologies incorporating responses to proximate stressors most consistently responded to late winter climate indices; in other words, the common climate signal in declining populations centered on late winter weather. Regional thaw-freeze events in 1986 and 1987 coincided with extremely low growth years throughout the region, a pulse of mortality (based on snag ages) and a rapid growth response consistent with competitive release. Analysis of paired healthy and declining sites in the same watershed suggested that thaw-freeze events may only be deleterious in the absence of insulating snow cover. If current trends continue, cedar dieback may expand upslope into healthy populations, raising concern for scientists and managers interested in maintaining this long-lived and valuable species in the temperate rainforest ecosystem of SE Alaska. Our study of the climatic correlates of yellow-cedar decline suggests several avenues of further research, such as mortality dynamics at a regional scale and the *in situ* timing of premature dehardening. Ongoing studies should provide better understanding of temperature-mediated dehardening in yellow-cedar, frost tolerance thresholds of active root tissues and the dynamics of snow cover during thaw-freeze cycles.

Table 2.1. Sites, sample size and regional groupings for aggregation of site chronologies.

Chronology		# sites	# trees
Total		19	254
Declining populations		17	227
Prince of Wales Island (POW)		8	90
	North POW	5	57
	South POW	3	33
Central Islands		6	72
	Mitkof	2	26
	Kupreanof	3	31
	Nemo (Wrangell)	1	15
Peril Strait/Sitka			
	Peril Strait	2	51
	Sitka	1	14
Healthy populations		2	27
	Poison Cove Bog	1	12
	Juneau	1	15

Table 2.2. Thaw-freeze events based on five weather records. Events were identified when at least seven growing days (MDT $\geq$ 5C) preceded at least two freezing days (MDT $\leq$ 0C) during February-April. Regional events (two or more stations) are in boldface. Annual winter snowfall descriptions are based on the number of standard deviations from the 1950-2004 mean; very low (-2 SD), low (-1 SD), average (within 1 SD), high (+1 SD), very high (+2 SD). Mean annual snowfall was calculated from several stations; snowfall data prior to 1950 was unavailable.

	Weather Station					
Year	Sitka	Little Port Walter	Ketchikan	Wrangell	Petersburg	Winter Snowfall
2003	**x**		**x**			Low
2001	x					Very Low
1997			x			Low
1996					x	Average
1995				**x**	**x**	Average
1989		x				Average
1987	**x**	**x**	**x**	**x**	**x**	Low
1980					x	Average
1978	**x**				**x**	Average
1974		x				Very High
1967		x				Average
1966				x		Average
1965	x					High
1955		x				Average
1953		x				Average
1944	x					-
1942	x					-
1934					x	-
1931	**x**		**x**			-
1927	x			x		-
1913			x			-

Table 2.3. Cross-correlations among regional aggregated mean tree-ring chronologies of yellow-cedar in declining populations, 1900-2004. Two healthy populations are included for reference: Poison Cove high elevation site (P. Cove Bog) and Juneau. Pearson *r* correlations are significant at the $p < 0.0001$ level when denoted by an asterisk (*).

	Mitkof	Kupreanof	Wrangell	Sitka	Peril Strait	North POW	South POW	P. Cove Bog
Kupreanof	0.67*							
Wrangell	0.72*	0.69*						
Sitka	0.68*	0.56*	0.54*					
Peril Strait	0.72*	0.61*	0.78*	0.81*				
North POW	0.66*	0.78*	0.57*	0.53*	0.59*			
South POW	0.51*	0.57*	0.51*	0.47*	0.58*	0.79*		
P. Cove Bog	0.28*	0.42*	0.40*	0.08	0.38*	0.48*	0.53*	
Juneau	-0.11	-0.11	-0.14	-0.37*	-0.33*	0.01	0.18	0.44*

Table 2.4. Components of multivariate climate models of cedar growth in declining stands during 1900-2004. Seven models (Sitka, Peril Strait, North POW, South POW, Mitkof, Kupreanof and Nemo) were built based on grouped cedar chronologies. Results are presented for both raw RWI and smoothed RWI datasets. Variables included all monthly mean temperature (MMT) and precipitation (MMPPT) from September of the growing season to the previous September (1-Sep). Stepwise regression models (JMP Fit Model) entered variables into the model at the $p < 0.1$ level. Only variables present in at least three models (of seven) are shown.

	Raw RWI				Smoothed RWI		
	Month	Frequency	Effect		Month	Frequency	Effect
MMT	May	3	positive	MMT	April	5	positive
	April	5	positive		January	3	negative
	March	6	positive		October (-1)	6	positive
	January	3	negative				
	November (-1)	3	positive				
MMPPT	April	7	negative	MMPPT	May	4	negative
	December (-1)	4	positive		April	6	negative
	November (-1)	4	negative		January	3	positive
	October (-1)	6	negative		December (-1)	5	positive
					November (-1)	3	negative
					October (-1)	4	negative

Figure 2.1. Hypothetical model of climate change as a driver of yellow-cedar decline in southeastern Alaska. We hypothesized that warming is leading to milder winters, an ultimate cause of cedar decline through: late winter thawing, early dehardening of yellow-cedar, reduced snowfall at low elevations, and earlier removal of insolating snow cover.

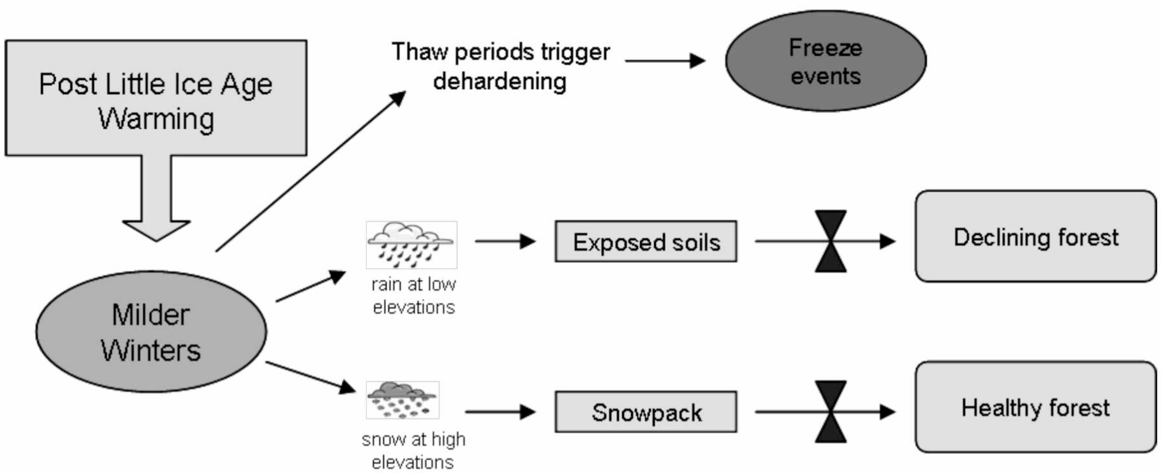


Figure 2.2. Maps of observed cedar decline, sample sites and weather stations in southeastern Alaska. Cedar decline map based on aerial surveys (Wittwer et al. 2004). All weather stations meet first order standards (since 1950) and are located at or near sea level.

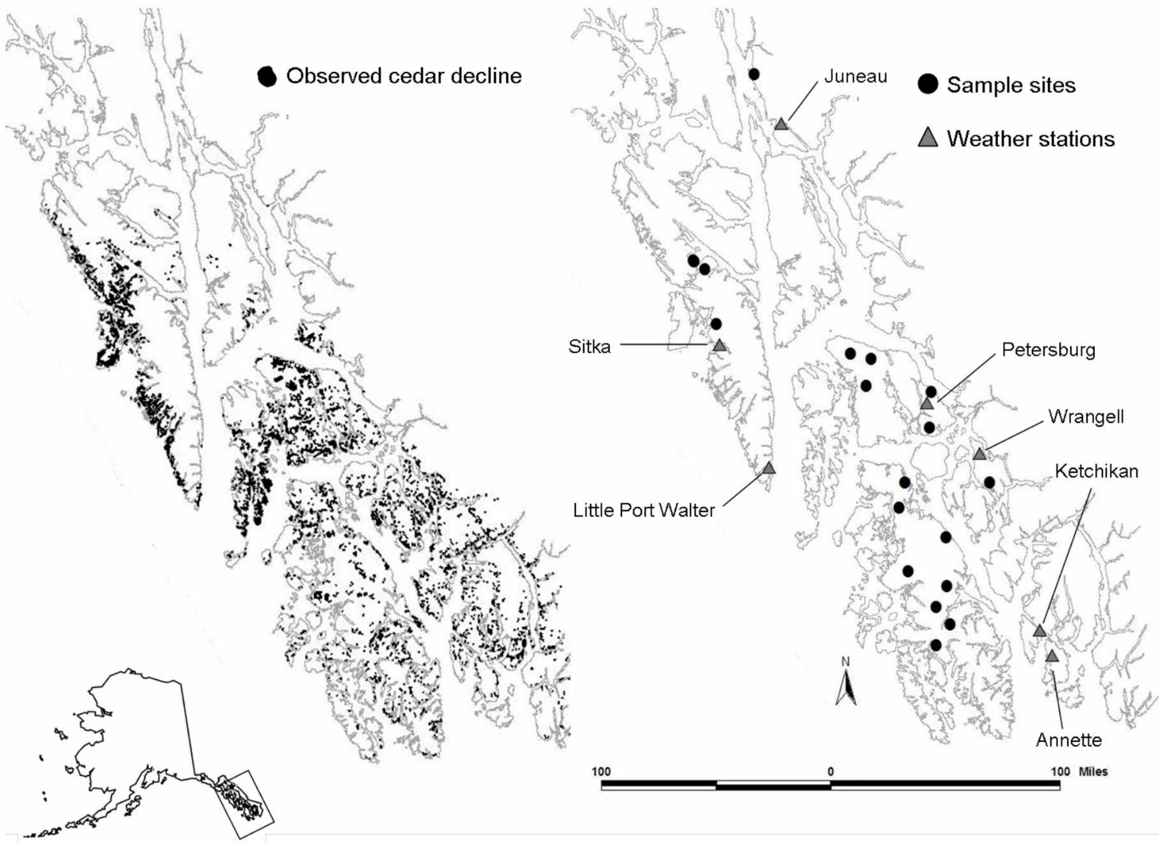


Figure 2.3 (a-d). Winter climate trends in southeastern Alaska during the 20th century. Based on simple linear regression models of Ketchikan-Annette combined weather records: a. winter rainfall 1910-2004 ($p < 0.005$); b. snowfall 1950-2004 ($p < 0.0001$); c. February mean monthly temperature 1910-2004 ($p < 0.0001$); d. March mean monthly temperature 1910-2004 ($p < 0.0001$).

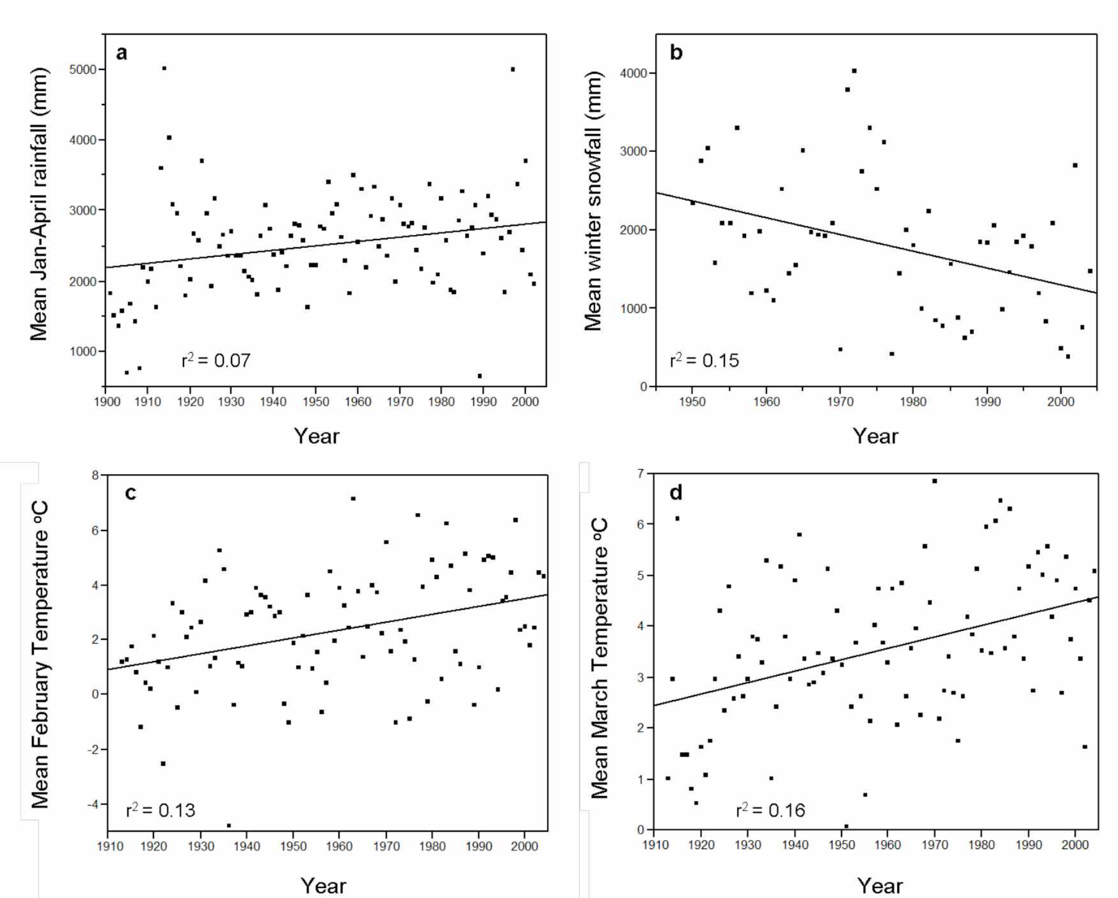


Figure 2.4. Major regional thaw-freeze event in 1987. Estimated thaw and freeze temperatures are provided as horizontal lines for reference.

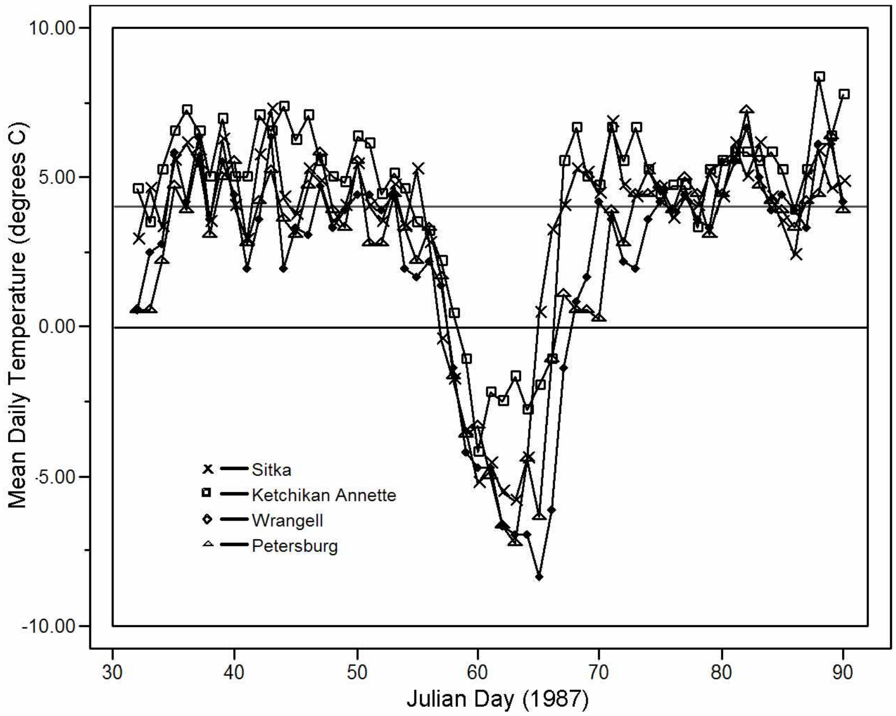


Figure 2.5 (a). Chronologies of declining populations, aggregated by sub-region showing common stress periods and marker years during 1900-2004. Ring width indices (raw RWI) are normalized to a period of 1900-2004, with a mean of zero.

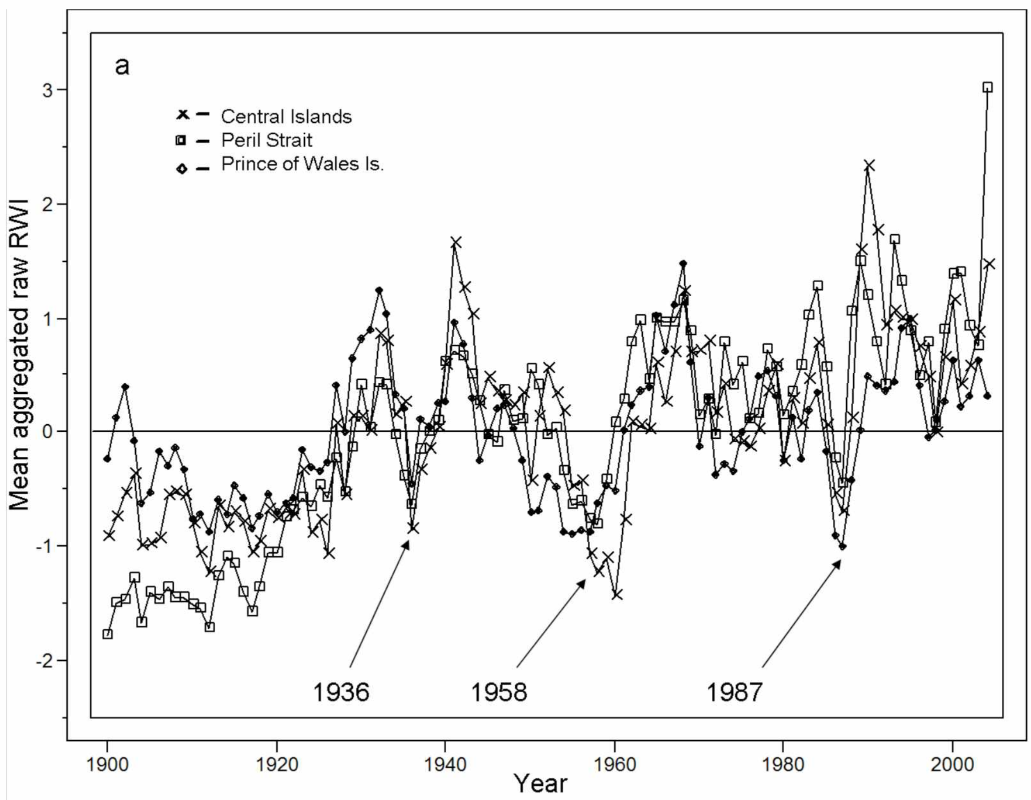


Figure 2.5 (b). An aggregated regional decline chronology with thaw-freeze events for reference. Data shown below are mean RWI calculated from all declining populations. Vertical lines indicate years where thaw-freeze event met the criteria in February-April of at least seven growing days (5C) preceding at least two freezing days (0C). Regional events were recorded at two or more weather stations; local events were observed at only one weather station.

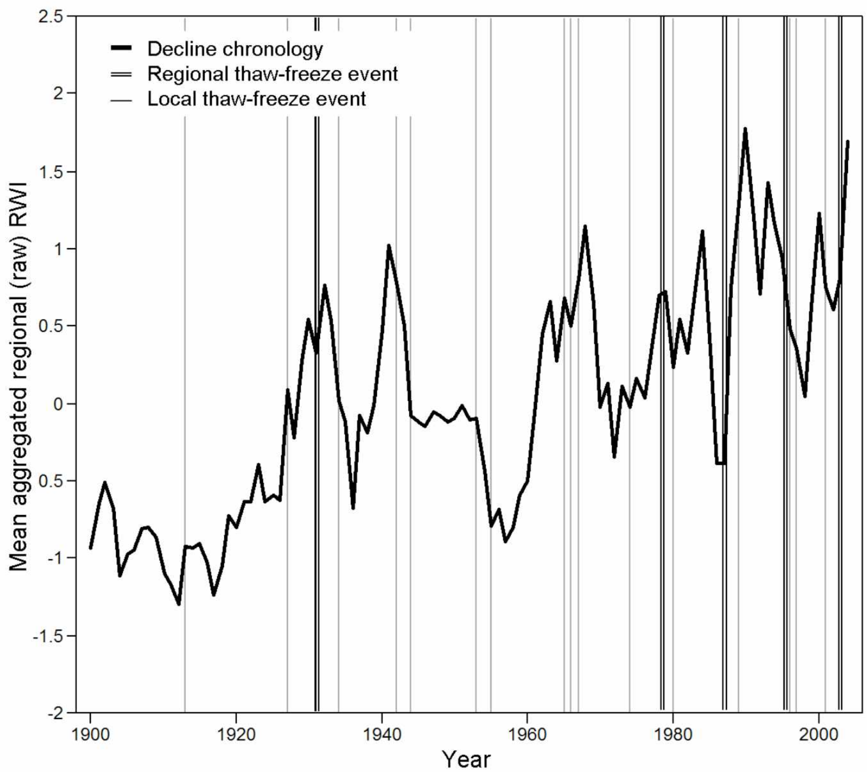


Figure 2.6 (a-c). Statistical and qualitative comparisons of cedar growth chronologies between paired sites in the Poison Cove watershed. The high elevation population is healthy and low elevation population is declining (since circa 1880). A linear model describing the similarity of growth signals between sites was partitioned by century, providing two regressions: a) 1800-1899; and b) 1900-2004. Regressions are plotted with 95% confidence intervals. The two chronologies normalized from 1800-2004 are plotted for reference (c).

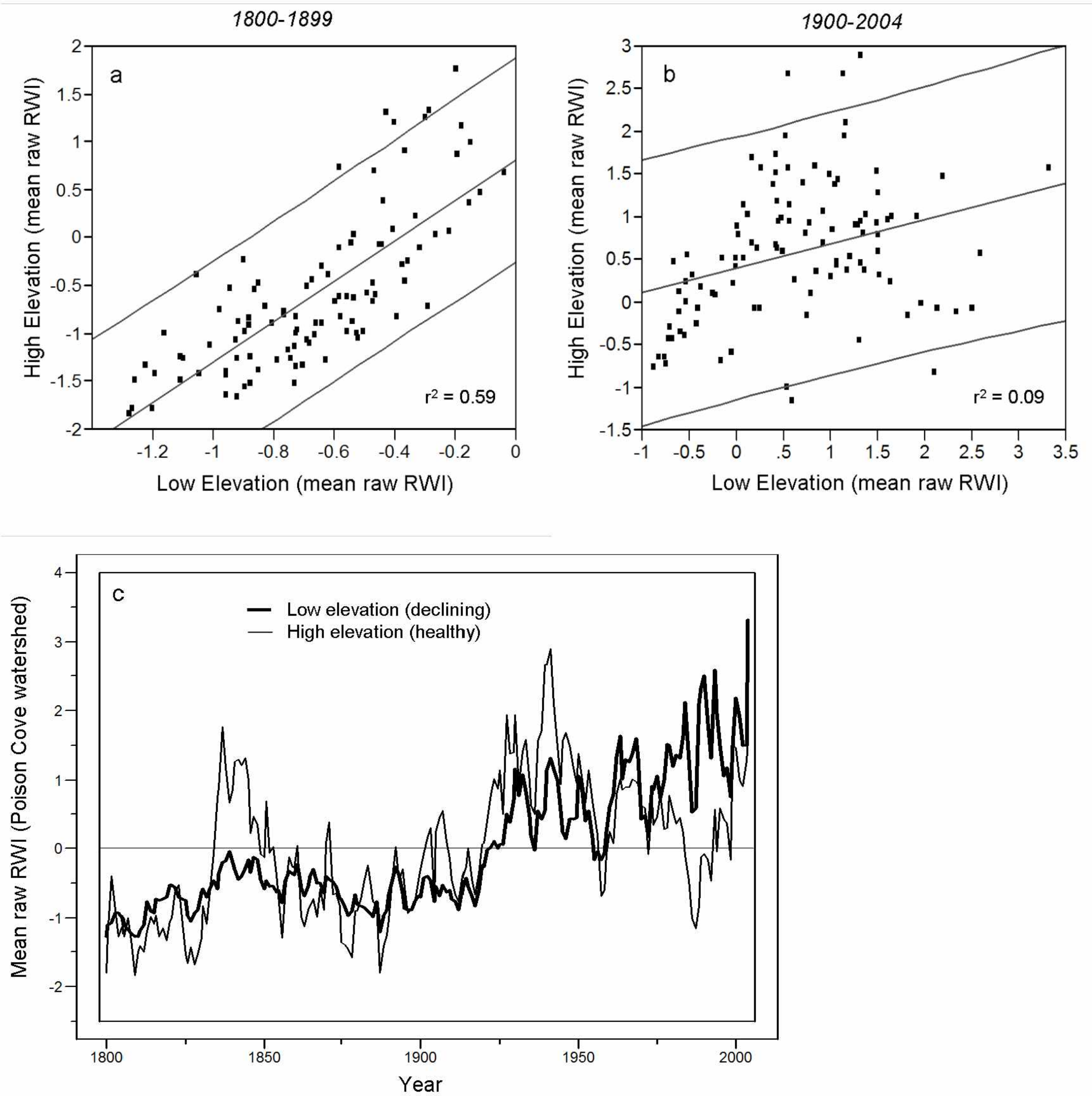
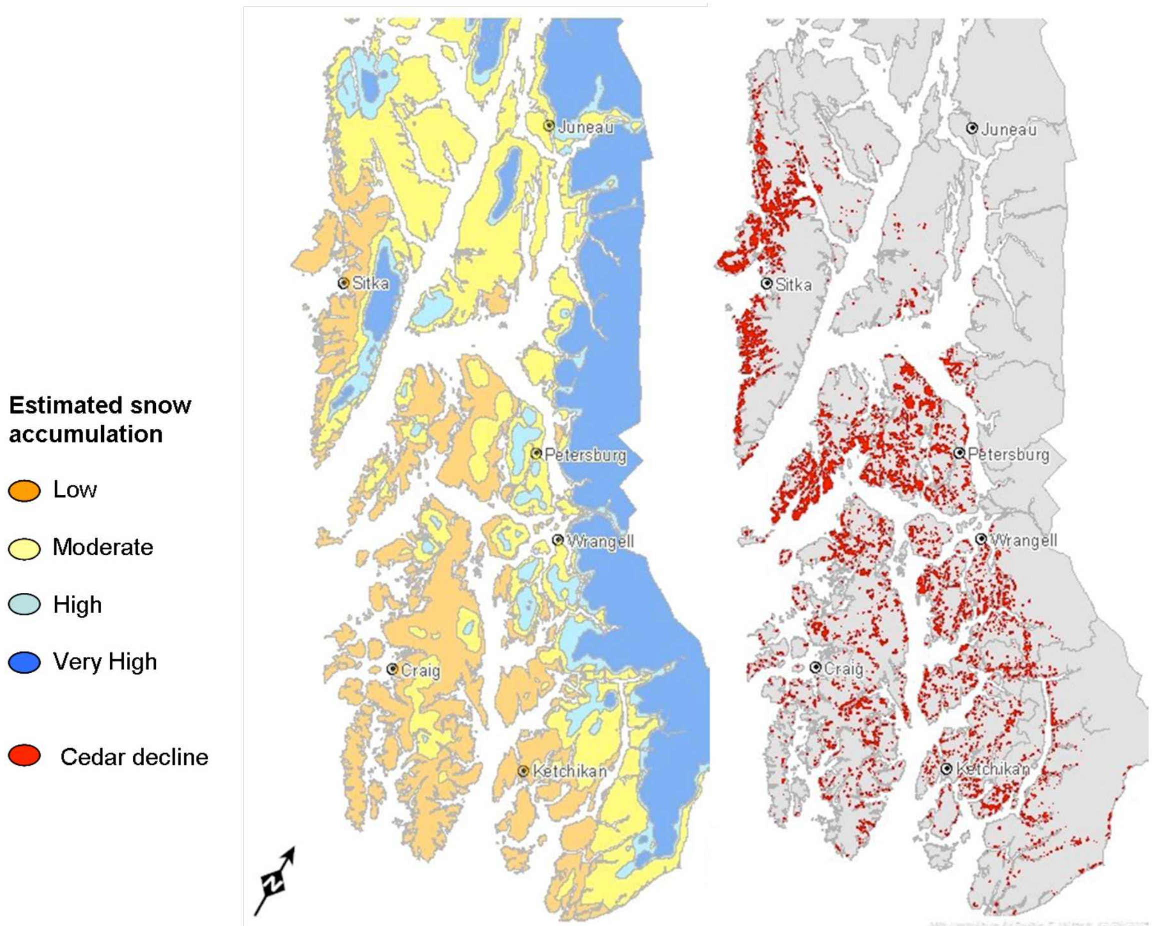


Figure 2.7. Maps of regional snow accumulation and the occurrence of cedar decline. Comparison of spatial patterns strongly suggests that most declining populations occur in "low" snow accumulation zones.



Chapter 3

Significance of wilderness conservation in Southeast Alaska: outcomes of the Alaska lands debate over the Tongass National Forest

3.1 Summary

The Alaska National Interest Lands Conservation Act of 1980 (ANILCA) designated over 100 million acres of Alaska as national parks, wildlife refuges, wild-scenic rivers and wilderness areas. Wilderness designation in the Tongass National Forest of southeastern Alaska was among the most contentious issues in the ANILCA debate, which resulted in a system of protected areas comprising nearly one-third of the Tongass. The challenge of designing reserves in the complex biogeography of SE Alaska and the influence of resource-extractive industries and local stakeholders on the ANILCA debate raise basic questions about the actual outcomes of federal conservation policy on the Tongass. Were the wilderness reserves created by ANILCA effectively designed from a conservation biology perspective? How did the opponents of reserves shape their design and management? What have been some of the broader outcomes of ANILCA in the ecosystems and economies of Southeast Alaska? To address these questions, this chapter presents a spatially-explicit assessment of the ecological importance of Tongass wilderness reserves and contextualizes these findings using a legislative history of ANILCA. I also present a partial analysis of the social importance of Tongass reserves, from the perspective of local uses such as hunting and fishing. In general, I found that Tongass wilderness protects a robust cross-section of ecosystems and species; although the most critical reserves were initially established by executive order, and subsequently redrawn during the ANILCA debate. Redrawn Tongass wilderness boundaries, industry subsidies, and special regulations reflected efforts to minimize the impact of wilderness conservation on mining, timber, and local stakeholder interests, respectively. Lastly, in the broader context of the dissertation, this chapter addresses

the policy subsystem of Southeast Alaska, its capacity to resist external change (i.e. the national environmental movement), and the resulting outcomes for the regional social-ecological system.

3.2 Background and rationale

3.2.1 History of the Alaska lands debate

In the first decade after Alaska statehood in 1959, it was imperative to settle land claims and partition Alaska's land and resources among state, federal, Native Alaskan and private interests. Development of the Prudhoe Bay oil fields discovered in 1968 was made conditional on settling the long-standing issue of Alaska Native land claims, resulting in the Alaska Native Claims Settlement Act of 1971 (ANCSA). An important provision in ANCSA was Section 17 d(2) that designated 80 million acres of public lands for 'national interest' consideration as parks, wildlife refuges, national forests, and wilderness reserves. The contentious debate over disposition of the d(2) lands framed a decade-long policy process that involved nearly sixty different federal bills, amendments and hearings. From 1973-1978, several Alaska lands bills failed in various House and Senate committees, while secret negotiations and other ad-hoc efforts failed to yield a compromise. The inability of Congress to reach a decision by 1978 prompted U.S. President Carter to withdraw by executive order 66 million acres of national interest lands across Alaska, including the Admiralty Island and Misty Fjords National Monuments in the Tongass National Forest. In addition to reinvigorating the Alaska lands debate and prompting Congressional action, this action brought the Tongass - which had been previously excluded from consideration - to the forefront of subsequent negotiations.

Perhaps for no other region in Alaska was the debate more contentious than when it focused on the Tongass National Forest of southeastern Alaska (Cahn 1982; Nelson 2004). Although the d(2) lands originally included none of SE Alaska, conservationists lobbied Congress and the Carter Administration for the creation of protected areas in the Tongass. At the time, nearly all of the forested areas of the Tongass were scheduled for timber harvesting, as deemed necessary to support the region's timber industry. Led by President Carter and Rep. Morris Udall (D-AZ), Chairman of the House Natural Resources Committee, conservationists sought to protect the wilderness character of the unique and productive natural landscapes of SE Alaska. On the other hand, the Citizens for Management of Alaska Lands represented mining, timber, and local stakeholders in opposition to the 'locking up' of the region's vast resources. Alaska's congressional delegation (Rep. Young, Sen. Stevens and Sen. Gravel) led a vigorous opposition to Tongass wilderness designation, arguing that it would constrain resource development and local subsistence practices in the region. The Forest Service also openly opposed wilderness measures on the Tongass (Nelson 2004). More broadly, the Alaska lands debate reflected the ideological struggle between federalism and the rights of western US states, as embodied in the 'Sagebrush Rebellion' of the 1970s (Gottlieb 1989).

During the 96th Congress (1979-80), Rep. Udall reintroduced HR 39 as the Alaska National Interest Lands Conservation Act (ANILCA). With the Tongass now included in the conservation debate, negotiations focused on how to preserve the region's social, economic, and cultural identity while preserving large areas of the landscape from human modification. Reflecting an overwhelming national public opinion in favor of preserving Alaskan wilderness, the House passed HR 39 by a 267-158 margin. The bill was sent to the Senate, where Senators Stevens (R-AK) and Jackson (R-WA) were instrumental in negotiating on behalf of both local concerns and several private industry interests in SE Alaska (Borell 2000). Stevens sought specific concessions on mining in Misty Fjords, oil exploration in the proposed Arctic National Wildlife Refuge, and protection for the timber industry in SE Alaska. After several modifications in the Senate, lawmakers passed a compromised version of HR 39 (e.g., reduced Tongass wilderness areas and authorization of mining operations in the Misty Fjords area) that was signed into law during the last weeks of the Carter

Administration. The final provisions for the Tongass included 5.3 million acres of wilderness reserves (designated as Wilderness and National Monuments), federal assurance of existing mining claims, land exchanges with Native corporations (created by ANCSA), additional support for Forest Service timber management, and subsistence-related exceptions to wilderness regulations.

3.2.2 Science and policy in design of protected areas

At first glance, Tongass wilderness reserves cover a diverse geography comprising nearly one-third of the Forest (Figure 3.1); an unprecedented amount of wilderness conservation in a timber-producing US National Forest at the time of ANILCA. However, the total acreage of Tongass wilderness reserves provides little insight on their regional significance for two reasons: the spatial heterogeneity of the physical and biological landscape (Noss 1990); and the tendency for commodity uses to preempt non-commodity uses in planning protected areas (Pressey et al. 2002).

First, if the goal of biological conservation is to maintain intact functional ecosystems, the conservation value of protected areas is dictated by ecological characteristics (e.g., community structure, productivity, species assemblages) in addition to other criteria (e.g., spatial heterogeneity, global scarcity), not the size alone (Noss 1983; Noss 1990). Compared to other National Forests, much of the Tongass is high elevation, unvegetated rocky terrain and glacial icefields with relatively low ecological importance compared to densely forested watersheds and stream habitats. For example, productive forestlands comprise about 39% of the total Tongass area, while wilderness reserves comprise 32%; thus it is possible that even the relatively large Tongass reserves may not meet conservation goals for productive forestlands. Old-growth forests were only one among several key ecological features of conservation interest in SE Alaska, including anadromous fish streams, estuaries, wetlands, and rare limestone formations known as karst (Cahn 1982; Nelson 2004). Since many of these ecosystem types are rare (e.g., wetlands and karst geology comprise about 9% and 3% of Tongass lands, respectively) and irregularly distributed across the landscape, designing the appropriate configuration of conservation units was difficult.

In SE Alaska, this challenge was compounded by the complexities of regional geography (e.g., steep montane terrain, island biogeography), endemic fauna (e.g., migratory avian and mammal populations, anadromous fish populations), land use policy (e.g., Native land claims, Tongass planning cycles) and drivers of change (e.g., warming climate, glacial retreat, coastal uplift, regeneration of second-growth forests). Alaska conservationists of the 1970s faced this challenge with neither the disciplinary basis nor the technology required for the rigorous landscape-scale approaches of modern conservation biologists (e.g. gap analysis). They also faced similar knowledge constraints about temperate rainforest ecosystem function, structure, and resilience that Tongass scientists faced two decades later while developing the 1997 Forest Plan (Shaw 1999; Shaw et al. 2000). For these reasons, it is unclear whether Tongass wilderness areas meet the basic criteria for effective conservation units, as defined in the current conservation literature (Noss 1990).

Secondly, the establishment of protected areas has historically excluded areas of current or future commodity production, especially when resource development interests play a role in policy formation (Pressey et al. 2002; Rodrigues et al. 2003). Because areas of high commodity value (in economic terms) often tend to have high conservation value (in biological, social, and cultural terms), conservation policy-making typically involves a debate in which economic interests are firmly established (Moffet and Sarkar 2006). This scenario epitomized the ANILCA Tongass debate, because opposing interests often valued the same ecosystems and landscape areas for very different reasons (Cahn 1982; Nelson 2004). First and foremost, opposing coalitions valued the most biologically productive and commercially valuable old-growth temperate rainforests, comprising about five percent of the Tongass. At the time, the existing timber industry was harvesting greater than 500 million bf/yr of old-growth Tongass forest, nearly all of which was sold under the long-term leases created by the Tongass Timber Act of 1947. Wilderness reserves, depending on their location, had the potential of reducing the available timber base below the minimum required to sustain these contracts in subsequent decades. Timber industry interests fought vehemently against this possibility, using their close ties to political (local, state and national policymakers) and institutional (Forest Service) authorities to influence the Tongass debate (Nelson 2004; Nie 2006). Moreover, Native Alaskan land claims had the potential of reducing the spatial integrity of reserves, because most of these private inholdings were also scheduled for intensive timber management (Cahn 1982).

Areas of high ecological, scenic, and wilderness importance in the Tongass also contained prospected and patented deposits of valuable metalliferous ores, including gold, copper, tungsten, platinum and molybdenum. Several unperfected mining claims would be included in the proposed wilderness reserves of HR 39, greatly limiting the exploration, access, and subsurface rights to those mineral deposits. Lastly, local residents sought to maintain the right to develop access and infrastructure in remote areas for subsistence and other purposes. These actions would be prohibited by the wilderness designation intended, in part, to protect local ecosystems and their resources for local benefit. Alaska's congressional delegation strongly represented these opposition interests in their pivotal role in framing ANILCA Tongass policy. They negotiated on behalf of several mining and timber companies (Borell 2000), as well as the Alaska Native corporations whose inholdings would be affected by wilderness designation; and worked in private sessions to lay out maps and 'redraw the lines' of proposed wilderness reserves (Cahn 1982; Nelson 2004). For these reasons, it is clear that opposing parties shaped the wilderness reserves in the Tongass, ostensibly in favor of resource-extractive land uses.

3.3 Objectives

In sum, the aforementioned factors raise questions about the influence of the ANILCA debate on the 'drawing of the lines' of Tongass wilderness reserves and the subsequent outcomes of regional conservation policy. Did conservationists design effective protected areas on the Tongass? How did the economic concerns driving the Tongass conservation debate influence the design of these protected areas? Historical accounts concur that ANILCA was a tenuous compromise in which neither opposing coalition was satisfied (Cahn 1982; Soderberg and DuRette 1988; Borell 2000; Nelson 2004). Yet it is difficult to determine the 'on the ground' outcomes of the Tongass debate, because significant questions remain unanswered about the ecological and social importance of the resulting protected areas.

Do Tongass wilderness reserves contain a robust cross-section of ecosystem types found in SE Alaska, including globally rare and/or highly productive ecosystems? To what extent do Tongass wilderness reserves support regional biodiversity, through habitat for fish, wildlife, avian and plant species? From the social perspective, how did the creation of wilderness reserves impact the local subsistence and commercial uses of fish and wildlife resources? In general, do federal wilderness protections that prohibit most forms of development have potentially offsetting benefits to the regional economy?

This study addressed these questions to better understand the 'on the ground' outcomes of the ANILCA debate and its final compromises over the Tongass. Despite the reporting requirements of ANILCA (Section 706(b)) that pertain specifically to the Tongass and "impacts of wilderness designation on regional industry, fisheries, wildlife habitat and subsistence," no prior reporting efforts have conducted a sufficiently rigorous analysis for this purpose. Such a study is needed because previous assessments have neither been spatially-explicit nor have they incorporated detailed ecological and social data. To this end, I conducted a spatially-explicit assessment of the ecological and social importance of Tongass wilderness reserves, using a ‘gap analysis’ methodology at a regional scale. Measures of ecological importance were based on landform, vegetation and species data, as well as higher-order estimates of focal species habitat capability, core ecological areas and rare/unique ecosystems. Measures of social importance focused on direct resource use (e.g., hunting and fishing) by local residents and existing infrastructure (e.g. roads and harbors). Using a geographic information system, I compared the physical, ecological and social features of legislatively-protected Tongass reserves to the remainder of Tongass lands under Forest Service management discretion. I contextualized these findings with a legislative history of ANILCA to describe how compromises among opposing interests are reflected in Tongass wilderness policy. Lastly, I discuss the broader outcomes of Tongass conservation policy with respect to major shifts in the regional economy post-ANILCA, related to decline of the timber industry and the subsequent growth of service and tourism sectors.

3.4 Methods

3.4.1 Study area

The 17.8 million acre Tongass National Forest is the largest in the US, comprising nearly eighty percent of southeastern Alaska, which is the territory bordering British Columbia, Canada including the Alexander Archipelago and coastal mainland, extending from Yakutat to Dixon Entrance (Figure 3.1). The region is characterized by its hypermaritime climate, complex island biogeography, mountainous terrain, coastal glaciers, salmon streams and dense conifer forests. Mild temperatures and abundant year-round precipitation support a globally rare and unique ecosystem: the coastal temperate rainforest. The region contains the largest tracts of unmodified temperate rainforest remaining in the world (Nelson 2004). Forests and wetlands provide habitat for a diverse flora and fauna, as well as the spawning and rearing grounds for five species of Pacific salmon. Despite spending most of their life cycle at sea, salmon (*Oncorhynchus* spp.) are keystone species that drive the terrestrial food web and provide large marine nutrient inputs to riparian forests (Shaw et al. 2001). Rocky coastlines, islands and protected bays support marine mammal and migratory seabird populations during various times of the year; many of these species are listed as threatened or endangered in other parts of the world.

Like much of the rest of Alaska, the southeastern region has a small permanent human population that resides mainly in a few urban centers and several much smaller rural communities. Of 34 towns, villages and permanent settlements, the cities of Juneau (pop. 31,000) and Ketchikan (pop. 13,000) comprise nearly two-thirds of the regional population. Island geography and the absence of a regionally integrated road network means that most communities are separated by large distances and are only accessible by boat or airplane. In short, these communities exist essentially as 'islands' within a 'sea' of Tongass National Forest land. Most permanent residents are Caucasian, with an approximately 25% population of Native Alaskans of Tlingit, Haida or Tshimshian heritage. In the past two decades, the SE Alaska economy has seen many changes: the collapse of its regional timber industry, with the closure of two major pulp mills and several associated sawmills; the concurrent growth in the visitor industry, especially in cruise-ship tourism through the scenic Inside Passage; and the decline in profitability of the seafood industry, due largely to external market forces (Crone 2004; Colt 2006).

3.4.2 Spatial data and geographic information system

A geographic information system (GIS; ESRI ArcView) was assembled using existing spatial datasets of ecological and social variables, based on sources of various origins (Table 3.1). Data layers were uniformly converted to $50m^2$ grid coverages, with the exception of linear features (e.g. streams and roads) and watershed-level data (e.g. primary/secondary salmon producing watersheds, Sitka black-tail deer harvest rates by watershed). The GIS provided an accurate 'snapshot' of the current spatial arrangement of landcovers, ecosystem types, habitat, human use intensity, and built infrastructure across the Tongass. Some data layers were used to estimate ecological potential regardless of current conditions. For example, forest data coverages were used to represent both standing forest (e.g., productive old-growth) and general site productivity (e.g., productive forest land including second growth created by timber harvest). Habitat suitability indices (HSI) are basic measures of ecological capacity to support populations, not actual population estimates. Core biological areas, based on a spatial optimization of multiple habitat and ecosystem criteria, represent the ecological 'hotspots' of SE Alaska (Albert 2006; I used a modified version of Albert's dataset). These datasets reflect the best possible approximation of current conditions, but they do not incorporate spatial or temporal dynamics, which are important for effective conservation planning (Noss 1990).

Social datasets suitable for GIS analysis included infrastructure (e.g., roads, recreation sites, harbors) and watershed-scale estimates of direct use intensity (e.g., game harvest, sport fishing). Hunting data were limited to harvest estimates of the 'urban' residents of Juneau and Ketchikan (about two-thirds of the regional population). Fishing data were limited to sport-fishing intensity by watershed, and did not include subsistence harvests by rural residents. Regional coverages of subsistence use intensity (of all residents), scenic values, and remote recreation were not available at the time of analysis. For the same reason, amenity, non-use (e.g., existence, bequest, option), cultural, spiritual, and other values of wilderness were not considered. Below I address these critical limitations of the social datasets, as well as the general limitations of the gap analysis conducted.

3.4.3 Data and analytical limitations

This study relied entirely on existing spatial datasets with extensive regional coverage; hence the limitations of the available data constrained the accuracy of the analysis and the applicability of its findings. Overall, the ecological datasets were more complete and detailed than the social data, but both datasets were limited by a lack of spatial or temporal components (and associated knowledge deficits; Shaw et al. 1999). The 'snapshot' approach has some utility in landscape ecology, but its application in social science is probably far less desirable. Given these fundamental limitations, I conducted an analysis with the best available information and interpreted its results with considerable caution.

Unfortunately, the majority of relevant social data for SE Alaska, such as subsistence and recreation use intensity, exist in a form not currently suitable for GIS analysis. Knowing this at the outset, it was not my intention to estimate the 'value' of Tongass wilderness to society, but instead to provide some insights on how wilderness areas may be used locally. The existing data allowed me to focus on local-scale use of fish and wildlife resources by certain user groups, e.g., hunting by urban residents of Juneau and Ketchikan, but not of the other 32 rural communities; sport-fishing, but not subsistence or commercial fishing. I included salmon-producing watersheds to describe to what degree the watersheds supporting commercial fisheries were represented in Tongass wilderness reserves.[2] I also used infrastructure data (e.g., recreation sites, harbors) as a proxy for use intensity, and hence a measure of social importance. These measures are narrowly focused at the local scale, yet they still comprise only a fraction of local uses and values of wilderness. For instance, we know that the pristine scenery and opportunities for isolation are important amenity values for local residents and economies (Shaw et al. 2001), but there has been no systematic accounting of these non-consumptive values in SE Alaska. If we expand the scope beyond the local scale and consider the multitude of non-use wilderness values, the focus of the social analysis herein becomes even narrower.

[2] By protection of fisheries, I refer to the maintenance of necessary terrestrial-aquatic habitats for spawning and rearing of salmonids. Salmon spend most of their life cycle at sea. Thus it is difficult to gauge the influence of terrestrial land use practices on salmon populations. These populations may experience cyclic decadal fluctuations due to a suite of factors that appear to be unrelated to terrestrial/aquatic habitat.

As a result, I only incorporated a fraction of the myriad social values of wilderness, as they exist for multiple stakeholder groups at multiple scales. While the non-use values of Alaskan wilderness (e.g., existence, bequest, cultural, spiritual) are very poorly understood in an empirical or spatially-explicit way, it is clear that national and global stakeholders have strong values for these wild places; SE Alaska is certainly no exception (Nie 2006). Many of these values were embodied in the broad upwelling of public opinion in favor of ANILCA and its designation of national interest lands (Nelson 2004). But because they have not been explicitly described as they vary across the landscape, there is no basis for evaluating whether ANILCA policy 'captured' these values. An understanding of these values and how they may differ across the landscape will require considerable effort in compiling existing data and conducting new research. In the meantime, I present a simplified analysis of the best available data and interpret the results accordingly.

3.4.4 Gap analysis

Gap analysis was used to evaluate whether ANILCA Tongass policy met two primary conservation goals: the representation of ecosystems across their natural range of variation, and the capacity to maintain viable populations of native species (Noss and Cooperrider 1994). Gap analysis provides an estimate of protected area representation of biogeographic 'elements' within a defined area, typically by overlaying management unit boundaries with ecological data in a GIS (Jennings 1995). Conservation efficacy can then be evaluated by comparing protected areas to target levels of representation (which tend to vary widely among studies). This study followed a similar approach that used area-weighted ratios as measures of equivalence between protected and non-protected areas. Area-weighted ratios allow comparison of land masses of different size; in this case, protected areas comprise about half the total area of non-protected Tongass lands. Area weighting created two hypothetical land masses of equal area for direct comparison. I therefore evaluated 'conservation efficacy' in terms of whether Tongass wilderness reserves were ecologically similar to the remainder of the Tongass.

Social variables of wilderness reserves were evaluated by gap analysis using comparison of area-weighted ratios. Two methods for area-weighting were required for the two types of data used in the social component of the GIS. Continuous variables (e.g., length of roads, bear harvest) were weighted by total acreage in each protection status. Watershed-scale rank attributes (e.g., primary salmon producing watersheds, deer harvest) were weighted by the total number of watersheds in each protection status.

Spatial datasets were overlaid with Tongass Land Use Designations (LUD) from the updated boundaries of the 1997 Tongass Land Management Plan (USDA 2003). At the regional scale, I calculated the total area (for grids) or length (for streams and roads) of GIS data elements within the following Tongass LUD groupings: *Wilderness* - strictly protected wilderness areas and national monuments; *Natural Setting* - Tongass lands permitting low to moderate levels of human modification, including some small-scale timber harvesting; and *Development* - Tongass lands scheduled for timber harvest, roads, or other resource-extractive uses (USDA 2003). The latter two groups were aggregated and parameter estimates were area-weighted for comparison of non-wilderness lands to wilderness reserves.

3.4.5 Interpreting the legislative history of ANILCA

To understand the terms of the Tongass-ANILCA debate and how various interests may have influenced the creation of protected areas, I compiled and interpreted a legislative history of ANILCA. The legislative history was based on executive and congressional records, scholarly articles, and journalistic accounts. I examined this history in qualitative and quantitative ways at progressively finer scales, from the broader ideologies of opposing coalitions, to the specific changes made in Tongass wilderness reserves during the HR 39 debate. First, I framed the philosophical terms of the broader debate using policy statements of relevant advocacy coalitions and interest groups (e.g., Cahn 1982; Gottlieb 1989; Borell 2000). Next, I searched the 93rd-96th Congressional records for bills and resolutions that contained 'Alaska lands' in the text and categorized each by general coalition: pro-wilderness, anti-wilderness, or neutral (bipartisan). To characterize each bill by coalition, I referred to either the text itself, or Library of Congress (LOC) legislative summaries, or the sponsoring legislator (in that order of preference; LOC summaries were used most often); sponsoring legislators were categorized based on their party affiliation, voting history, and/or historical role in the Alaska lands debate. This analysis provided an estimate of each coalition's strength in Congress during the years leading up to ANILCA.

Third, I tracked Tongass-related provisions through the progression of Rep. Udall's Alaska lands bill (HR 39) that eventually became ANILCA. There were six different versions of HR 39 during the 96th Congress, and each successive version involved the addition, subtraction and modification of specific provisions and amendments. The most Tongass-pertinent sections of HR 39 were Title IV (National Forests) and Title VI (National Wilderness System); these titles were changed to Titles V and VII, respectively, in the final text of ANILCA. I coded each provision and amendment as it pertained to: creation of protected areas, timber, fisheries, Native land claims, subsistence, recreation, and mining. I tracked the number of, and changes to, these provisions and the number of wilderness areas through the six versions of HR 39. This approach did not describe detailed changes to protected area boundaries, nor could it provide a 'running estimate' of the total prescribed area of Tongass wilderness as it changed during the policy process. Changes to specific wilderness reserve characteristics (e.g., size, extent, spatial dimensions) were difficult to trace, due to the lack of public records describing how wilderness boundaries were redrawn by legislative staffers and lawmakers during private negotiations. I relied primarily on legislative summaries and journalistic accounts for insights on these types of changes (Cahn 1982; Hawley and Wiggins 2000; Nelson 2004).

3.5 Results

3.5.1 Representation of ecological elements

Overall, wilderness reserves achieve about 30% mean representation of Tongass ecosystems (Figure 3.2), based on groups of variables that were averaged to estimate the weighted area ratio of each ecosystem/habitat type (e.g. landcover, forests, salmon, etc). Since reserves comprise 32% of Tongass area, this suggests that Tongass wilderness reserves are similar to non-wilderness Tongass lands in the representation of most ecological elements. Detailed gap analysis results based on area-weighted ratios are presented in Figure 3.3(a-e). Wilderness reserves contain proportionally equivalent areas of keystone ecological features such as old-growth conifer rainforest, highly productive riparian forests ('big-tree riparian'), palustrine wetlands (bogs, fens and muskegs) and wildlife habitat. Core ecological areas, the 'hot-spots' of productivity and biodiversity in SE Alaska, are well-represented in wilderness. The representation of salmon streams was variable by species (Figure 3.3c); chinook salmon (*O. tshawytscha*) habitat was higher in wilderness, but lower overall for the other four species, especially coho (*O. kisutch*) and sockeye (*O. nerka*). None of the mapped rearing areas for pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*) are within wilderness reserves; however this result probably reflects data limitations (i.e. small sample sizes) rather than patterns of distribution. Reserves have a higher proportion of high-elevation alpine communities, non-forest vegetation, rivers, subtidal estuaries, and migratory habitat for gulls and shorebirds. Reserves have a lower proportion of karst, second-growth forest, glacial ice, flood plains, riverine and intertidal estuaries, riverine wetlands, and waterfowl habitat. Thus overall, the Tongass wilderness reserves created by ANILCA represent a mostly comprehensive cross-section of the ecosystems and habitats in SE Alaska.

3.5.2 Representation of social elements

Spatially-explicit datasets with regional coverage of social variables were limited to watershed-level measures of fishery productivity, fish and game harvest, and basic infrastructure (e.g. roads and recreation sites). Based on area-weighted ratios (Figure 3.4), Tongass wilderness reserves are equally representative of salmon-producing watersheds (that supply commercial, sport and subsistence fisheries), primary sport-fishing areas, brown bear harvest, deer harvest by Juneau residents, and recreation sites. Wilderness reserves include 48 (28.8%) of the 167 primary salmon-producing watersheds (that in total comprise about two-thirds of all salmon production by volume in SE Alaska), and 26.2% of all salmon-producing watersheds across the region. Twenty-seven percent of U.S. Forest Service recreation sites, such as public use cabins, are located in reserves. Brown bear harvest and Juneau residents' harvest of deer are proportionally higher in wilderness; conversely, black bear harvest and Ketchikan residents' harvest of deer in wilderness are proportionately much lower. Roads and infrastructure are negligible in wilderness reserves; this was an expected result given that roads and nearly all forms of human modification are prohibited in wilderness. Thus overall, despite the access limitations imposed by wilderness designation, the available data suggest that some wilderness reserves are important places for hunting, fishing, and recreation uses. These results should be interpreted with a large degree of caution because of the serious analytical limitations imposed by data paucity, and a considerable body of anecdotal evidence suggesting that wilderness strongly limits local access (Borell 2004; Nelson 2004).

3.5.3 The Tongass wilderness debate

The original configuration of Tongass wilderness reserves – as designed by the pro-conservation Alaska Coalition – was introduced in Title VI of HR 39, by Rep. Udall (D-AZ). Udall used his seniority and committee chairmanship to have HR 39 scheduled first on the docket, meaning that alternative d(2) bills would only be considered if HR 39 failed to pass the House. HR 39 included the Admiralty Island

and Misty Fjords National Monuments, a measure that ratified the executive order that established them in 1978.

Based on review of 'Alaska lands' bills introduced during 1975-80, the coalition opposing wilderness[3] was relatively weak in the House, compared to the Senate (Table 3.2). This is partly due to the fact that the less populous western states have a greater representation in the Senate; most of these states' lawmakers opposed ANILCA as another case of federalism impinging on state sovereignty.[4] Despite the apparent weakness of ANILCA opponents in the House during the 96th Congress (1979-80), House committees reported two amended versions of HR 39 that reduced the acreage of Tongass wilderness designations and eliminated both National Monuments. In response, Rep. Udall introduced HR 8311, which expanded wilderness areas and included several other conservation-oriented measures (see Appendix A). In the final version that passed the House, Tongass wilderness designations most closely resembled the original HR 39 configuration, including both National Monuments. Negotiations in the Senate, led by Sen. Stevens (R-AK) and Jackson (R-WA), eliminated two wilderness areas (Idaho Inlet and King Salmon Capes) and temporarily removed the Monument designation from Admiralty Island. Several compromises related to timber, Alaska Native claims and mining (described below) were required to re-establish Admiralty Island National Monument (AINM) in the final legislation. Nevertheless, HR 39 was the first state-specific bill to pass the Senate over the strong objections of its two Senators (Borell 2000; Nelson 2004).

Compromises on Tongass wilderness were necessitated by the interests of local stakeholders (e.g., subsistence, access rights), resource-extractive industries (e.g.,

[3] ANILCA was broadly opposed by a movement known as the Sagebrush Rebellion (after 1980, known as the Wise Use Movement; Gottlieb 1989). The movement argued that large federal land holdings impinged on the sovereignty of western US states and advocated for the transfer of federal lands to state control. Two unsuccessful 'Sagebrush' bills were introduced in 1979 during the ANILCA debate.

[4] HR 5662 (Young-AK) and HR 7837 (Santini-NV) both created a 'federal lands transfer board' to oversee the conveyance of public lands to state ownership; neither bill received a vote in the House.

timber and mining), and Alaska Native corporations. Based on the frequency and content of Tongass-relevant provisions in National Forest and Wilderness sections of HR 39, timber interests were the most influential, followed by mining and Native claims (Table 3.3).

The timber issue was contentious enough to warrant special attention (nine provisions) in HR 39 introduced by Rep. Udall. Timber-related provisions instructed the Secretary of Agriculture (SOA) to exchange lands under contract that would be designated as wilderness with other commercially viable forests, to support loan programs for equipment and technology, and to conduct research on improving productivity, yield and processing efficiency. An unadopted amendment[5] to HR 39 prescribed Tongass 'special management areas' where a ten-year harvesting moratorium would be lifted by the SOA to meet industry demand. Also known as "pulp banks" (Nelson 2004), this idea was proposed in previous d(2) bills and was strongly supported by the Forest Service.

Alaska Native claims interests were a considerable part of the coalition opposing HR 39 wilderness in the Tongass. Moreover, Native claims provisions dealt almost exclusively with timber rights. In exchanging lands for those withheld in wilderness, a key issue was the right to select lands where HR 39 sought to establish the AINM. Nearly all timber-related Native claims provisions dealt explicitly with Admiralty Island, leading to some fragmentation of the AINM.

Mining interests in the Tongass were not strongly reflected in any House version of HR 39, but were heavily emphasized by the Senate (Table 3.3). House provisions dealt with impacts on freshwater fish habitat, defining rights of claim holders, and providing a five-year grace period to develop unperfected claims in Tongass

[5] This provision was referred to the House Committee of Merchant Marine and Fisheries (where much of the ANILCA negotiation occurred) via HR 2199, a bill that reduced the total number and area of Tongass wilderness reserves from HR 39. It was included in both amended versions of HR 39 reported from committee, but was eliminated in the final House version.

wilderness areas. Senate provisions more strongly reaffirmed the rights of permit holders, set no time limits on development of unperfected claims, and specifically addressed the Quartz Hill area of Misty Fjords National Monument (MFNM). Senators Stevens and Jackson negotiated specifically on behalf of US Borax Co. (Hesse and Smith 2000), who held the existing patent to develop the Quartz Hill molybdenum deposit that was jeopardized by creation of MFNM. By this point, Forest Service decisions to build access roads to Quartz Hill were already being challenged in federal courts by the Sierra Club and the Southeast Alaska Conservation Council (SEACC). The resulting provisions of ANILCA required the completion of environmental impact statements (EIS) for access roads, bulk sampling and offshore disposal of tailings. The SOA was required to permit these activities unless the EIS demonstrated that fish habitat would suffer 'substantive, irreparable damage' from development of Quartz Hill. Another provision allowed the developers of Quartz Hill and Greens Creek (an existing mine on Admiralty Island) to lease necessary lands from the Tongass, at fair-market value. Overall, the mining-related measures in ANILCA were successful in legitimizing the two largest mineral extraction operations in the region, which resulted in some minor fragmentation of the AINM and MFNM.

Fisheries, recreation, and subsistence provisions in HR 39 generally sought to maintain the status quo for local residents and reduce access limitations for certain uses of wilderness. Fisheries provisions authorized research, management and restoration of anadromous fisheries and established regulations for protection of aquatic habitat from mining-related disturbance. Recreation provisions established a grandfather clause for permits of existing campsites and dwellings in wilderness areas and authorized maintenance of, and limited additions to, public use facilities. Since the subsistence issue was addressed in a separate title, there were few provisions in Titles IV and VI. Those pertaining to the Tongass reaffirmed the subsistence priority and required the SOA to permit subsistence uses in National Forest Wilderness and Monument lands.

3.6 Discussion

3.6.1 Influence of the policy debate on conservation planning

ANILCA Tongass policy created protected areas that represent a robust cross-section of ecosystem types in SE Alaska, despite the challenges of reserve design and the numerous compromises required in framing the legislation. Overall, my findings - based on a synthesis of gap analysis and policy analysis - suggest that conservationists achieved their broad goals in the Tongass debate, with some caveats. In particular, the designation of AINM was a major achievement because Admiralty Island contains the largest continuous pristine areas of productive old-growth temperate rainforest and high quality wildlife habitat of all reserves. From an ecological perspective, AINM is clearly the keystone conservation unit in the northern half of the Tongass, but it was not achieved without substantial compromise.

I found three cases where wilderness reserves were clearly fragmented by legislative compromises, two of which dealt with AINM. On Admiralty Island, conservationists sought measures to prevent Native corporations from selecting replacement lands (primarily for their timber) that could potentially degrade the wilderness character of AINM. In a compromise, certain lands were conveyed to Native ownership on Admiralty Island. A portion of these lands was subsequently logged, resulting in the largest continuous clearcut in North America, situated centrally along the western coast of AINM (Figure 3.5). While most of the remaining Native inholdings on Admiralty Island are managed as the Kootznoowoo Wilderness, the landowners retain timber rights and may harvest at their discretion. Two patented mineral deposits – located at Greens Creek on northwest Admiralty Island and Quartz Hill in the central Misty Fjords area – required compromises that led to some fragmentation of the AINM and MFNM. The Greens Creek patent was instrumental in removing the northernmost area of Admiralty Island (known as Mansfield Peninsula) from wilderness designation. Yet overall, while these mineral leases have a minor impact on the spatial integrity of protected areas (e.g. the Quartz Hill mine area comprises 153,000 acres of the 2.9 million acre MFNM), the environmental impacts of subsurface mining are potentially significant far beyond their geographical footprints. Conservationists continued their opposition to Quartz Hill in federal courts, despite the ANILCA settlement, and the mine was closed in 1985.

Another caveat is that Tongass reserves may be less effective in protecting aquatic habitat for four Pacific salmon species, especially coho-rearing and pink-spawning areas. Prior to Tongass-wide implementation of riparian buffers (Tongass Timber Reform Act of 1990), wilderness provided the only strong protections to riparian forests in major salmon-producing watersheds. Although the regional fisheries are scientifically managed and appear healthy, the negative impacts of logging-related disturbance are poorly understood. Fishery improvements funded partially by ANILCA may have offset these impacts by supplementing local and regional stocks (e.g. hatcheries and aquaculture).

3.6.2 Significance of ANILCA in Southeast Alaska

In the twenty five years since ANILCA became law, dramatic changes in the regional economy of SE Alaska have been signaled by collapse of the forest products industry and rapid growth of tourism and guide/outfitter industries. The concern over the impact of ANILCA policy on the SE Alaska economy was reflected in Sections 706(a) and (b), requiring annual reports on timber supply and demand, and biennial reports on the impact of wilderness conservation on regional industry and subsistence. These reports ostensibly sought to ensure that key compromises in the legislation were implemented, because opposing interests agreed to ANILCA on the condition that federal land protections would not unfairly restrict subsistence or economic growth through resource extraction. However many Alaskan stakeholders and their representatives have expressed growing discontent with the 'broken promises' of ANILCA (Stevens 2000; Borell 2000). In SE Alaska, these grievances focused on subsistence, timber, mining and reasonable access to resources. For example, many Alaskans find fault in the enforcement of wilderness regulations[6] that strictly limit the 'customary and traditional' uses assured to them by the Alaska State Constitution and the Alaska-specific wilderness regulations of ANILCA.

Subsistence access to fish and wildlife resources was a primary concern of the Alaska lands debate. A full discussion of the complex issues associated with ANILCA and subsistence is beyond the scope of this study. Yet the ongoing conflicts associated with ANILCA suggest that access and infrastructure limitations may exclude subsistence users, despite the extensive legislative measures to ensure subsistence rights to rural residents. Based on my limited analysis, however, ANILCA wilderness designations do not appear to categorically exclude local use of fish and wildlife resources in the Tongass, although some resource- and place-specific variation was observed. For example, brown bear hunting is more common in wilderness reserves, despite access limitations, because of the high density of brown bears on Admiralty Island. Deer hunting by Juneau residents is also common in wilderness reserves, due in part to the close proximity of AINM. By contrast, harvest of black bear and deer by Ketchikan residents is much lower in wilderness reserves. These results should be interpreted with caution, because the available data was very limited, and preliminary surveys suggest that rural subsistence users choose to focus their activities on non-wilderness lands (ADF&G 1998).

Since ANILCA, the SE Alaska timber industry has experienced a dramatic decline. ANILCA withdrew 1.6 million acres of productive old-growth forest from potential

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[6] Wilderness regulations typically prevent the use of mechanized transport to access remote areas, including all-terrain vehicles, snow machines, and helicopters. The special provisions in ANILCA had the intent of loosening many of these restrictions to ensure the subsistence rights of local residents. However, because of vague language in ANILCA, the intent of these exceptions has been interpreted in many ways.

timber development, representing about one-third of the commercially viable stands in the Tongass. This acreage equates to about three times the total acreage harvested during the first four decades of Tongass commercial logging. However, the acreage harvested from 1960-2000 represents less than twenty percent of the available Tongass timber base as it existed immediately after ANILCA wilderness designations took effect. Given that most second-growth stands are managed on a 100-150 year rotation, it appears that ANILCA left behind a sufficient timber base to sustain harvest rates at the time. In fact, timber provisions for the Tongass instructed managers to improve second-growth yield via thinning, to accelerate harvest rotations and improve timber quality. While the decline of the regional timber industry has often been attributed to shifts in public lands and environmental policies (Soderberg and DuRette 1988; Borell 2000; Nie 2006), ANILCA was only one of several policies that contributed to reductions in the Tongass timber base. The Tongass Timber Reform Act (which created riparian buffers), the National Environmental Policy Act (which has facilitated legal opposition to Tongass timber sales by environmental advocates) and the designation of 'Natural Setting' (LUD II) lands in the 1997 Tongass Land Management Plan were probably more detrimental to the regional forest products industry (Nie 2006). In the conclusion of this chapter, I provide a discussion of this topic as an introduction to the subsequent chapters (4 and 5) on the rise and fall of the Tongass-based timber industry in SE Alaska.

The broad impacts of ANILCA on mining in SE Alaska are unclear, because the degree to which wilderness designation has inhibited mineral exploration is probably significant, but unknown. However, relative to other areas in Alaska, mining interests in Southeast received the most accommodation in the designation of federal conservation units. Both the Greens Creek and Quartz Hill mines were excluded from the 1978 withholding by President Carter, as well as the final boundaries of Admiralty Island NM and Misty Fjords NM. The terms of the US Borax patent at Quartz Hill were heavily negotiated until a compromise was achieved that allowed immediate development. The massive molybdenum deposit at Quartz Hill was partially developed but eventually was forced to close, due to market factors and environmental litigation. The Greens Creek mine remains in operation on northern Admiralty Island, with a clean environmental record.

Access is by far the scarcest resource throughout Alaska, and given the rugged, island terrain of the region, SE Alaska is no exception. One of the major 'promises' of ANILCA to the people and industries of Alaska was that reasonable access would be allowed through conservation units that normally prohibit roads and mechanized forms of transport (Hawley and Wiggins 2000). The concern was that resources not 'locked up' by wilderness could still remain out of reach if people could not access them. Special compromises were made to allow an unprecedented level of access through protected areas in Alaska, although many stakeholders claim these became another 'broken promise' of ANILCA (Borell 2000). With the exception of mine-related and pre-existing roads, Tongass wilderness areas are roadless and more difficult to access for a range of uses, including subsistence. Broad language and vague provisions have allowed a range of interpretations of the access-related policy of ANILCA, which can vary widely depending on the national political climate. Given the ongoing controversy over ANILCA-related access limitations (Hawley and Wiggins 2000; Stevens 2000; Nelson 2004), it appears that the management of Alaskan wilderness has failed to meet the expectations of local stakeholders and their representatives. For these reasons, the access issue remains perhaps the greatest legacy of ANILCA in much of Alaska today.

3.7 Conclusions

Based on my finding that Tongass wilderness reserves constitute a robust cross-section of SE Alaska ecosystems and habitats, an important conclusion of this study was that commodity interests did not supersede conservation interests in the creation of protected areas. This finding was contrary to the prior research upon which I based the second rationale of this study, and was especially interesting given the strong influence of resource-extractive industries on the ANILCA debate over the Tongass (Pressey et al. 2002; Rodrigues et al. 2003; Moffet and Sarkar 2006). Why this outcome for SE Alaska? One reason was that SE Alaska conservation planners had a favorable situation because nearly all of the regional landscape was in an unmodified condition at the time. This permitted the creation of very large wilderness areas that comprised numerous intact watersheds, thus encompassing a number of functional ecosystems across the landscape. Moreover, because roads and infrastructure were scant or non-existent in so much of the SE Alaska landscape, it was probably easier to design wilderness reserves in the region compared to other more intensively developed regions. This factor may have also made the creation of these reserves more politically acceptable, because there was very little physical evidence of human use or habitation in these places. For these reasons, it appears there was enough 'room' for both resource development and wilderness conservation on the Tongass, notwithstanding the conflicts related to subsistence.

From the perspective of SE Alaska as a social-ecological system (SES), the protection of vast natural landscapes is important in many ways, including subsistence. Protection of natural capital tends to support biological and economic diversity that is critical during periods of change (Carpenter et al. 2004). During a period of climatic, economic and socio-political change in SE Alaska, the maintenance of intact ecosystems and their services may be critical to regional SES resilience.[7] For example, Tongass reserves prevent direct modifications to the aquatic habitats of nearly one-third of major salmon producing watersheds responsible for commercial, sport and subsistence fisheries. Pacific salmon are the primary basis (by volume) of SE Alaska commercial fisheries, a major sector in the regional economy and a major source of income for several communities. Wilderness designations also protect a

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[7] See Chapter 6 for an assessment of ecosystem services with respect to ANILCA wilderness protections. This assessment is used to describe the regional resilience afforded by conservation policy in SE Alaska.

large proportion of marine estuaries that are critical for other fisheries, including crabs and shellfish. Likewise, the protection of fish stocks and pristine scenery important for sport-fishing has likely been beneficial in the rapid growth of the regional guide/outfitter and visitor industry. The benefits to remote recreation, scenery and ecotourism are difficult to quantify, but several wilderness areas are major tourist destinations. The wild character of the SE Alaska landscape provides the amenity values important to the rapidly expanding visitor industry, which has become a major component of the SE Alaska economy in recent years (Colt 2006). In this way, ANILCA wilderness protections may have afforded a smoother economic transition since the decline of the regional timber industry; this topic is discussed further in Chapter 6.

The systems perspective also helps us to understand regional dynamics in response to shifts in national public opinion that were largely external to the region. These shifts were not entirely external to the region because the group of conservationists that designed the Tongass wilderness reserves included many local citizens and scientists. There was a small but effective grassroots organization of Alaskan residents that supported ANILCA from the local level (i.e. the Alaska Coalition; Cahn 1982). Yet the vast majority of Alaskan stakeholders opposed federal land withdrawals, and despite the extensive negotiations to reach a compromise, Alaska's congressional delegation strongly objected to ANILCA in its final form. ANILCA is widely viewed in Alaska as a major victory for environmentalists, and thus a defeat for most Alaskans (Soderberg and DuRette 1988; Borell 2000; Hawley and Wiggins 2000). For these reasons, we can consider ANILCA policy in SE Alaska to be an outcome of the exogenous influence of national public opinion. The policy subsystem of the SE Alaska SES (as defined in Chapter 1) acted to mitigate the influence of this exogenous driver of change, and was variably successful in resisting this perturbation, depending on the interests at stake.

In the broader context of this dissertation, I used this case study to closely examine the dynamics of the SE Alaska policy subsystem in response to external perturbation. Based on my findings, the policy subsystem was most effective in protecting timber interests in the framing of ANILCA Tongass policy. While ANILCA did shrink the Tongass timber base significantly, enough timber remained to satisfy the volumes guaranteed in the long-term leases. In this way, the policy subsystem stabilized the larger-scale federal management system of SE Alaska by maintaining the legislative and economic basis of industrial forestry, the primary thrust of Tongass management in the 20th century (Nie 2006). Therefore, as a source of larger-scale resilience in the response of federal management to strong external perturbation, we can describe the policy subsystem in a 'conservation phase' of its adaptive cycle (see Chapter 1), and interpret the ANILCA debate as a struggle between internal stabilizing processes and exogenous drivers of change. This perspective is fully developed in the next chapter, where I frame the history of Tongass management using the adaptive cycle metaphor.

Table 3.1. GIS data coverages, methods, and sources.

Group	Description	Units	Method	Data/Source
Landcover types		acres		
	Productive Old-Growth Forest (POG)		all POG classes	TIMTYPE [1]
	Old-growth Conifer (OGC)		POG, all stands > 200 yrs	""
	Conifer Forestlands (CF)		POG, OC, second-growth	""
	All Forest		CF, deciduous forest	LANDCOV [2]
	Non-forest vegetated		alpine, non-forest veg.	""
	Unvegetated		ice, avalanche zone, rock	""
	Ice		n.a.	""
	Alpine		n.a.	""
	Core ecological areas		MARXAN (multiple criteria)	""
	Cut forest (second growth)		n.a.	TIMTYPE [1]
High productivity forest		acres		
	Big Tree Riparian		n.a. (TNC model)	BT_FOREST [2]
	Medium Tree Riparian		""	""
	Big Tree Upland		""	""
	Medium Tree Upland		""	""
	Riparian Second Growth		""	""
	Upland Second Growth		""	""
	Karst topography		n.a.	KARST [1]
Wildlife Habitat		acres (by quartile)		
	Deer		upper three quartiles of HSI	TLMP model [1,2]
	Bear		""	""
	Murrelet		""	""
	Migratory waterfowl		by species group	ESI_BIRD [3]
Salmon Habitat		meters (by species)		
(five species: king, coho, sockeye, chum and pink)				
	Present		n.a.	AWC [3,4]
	Spawning		""	""
	Rearing		""	""

Key to data sources and acronyms: 1 – SE Alaska GIS Library, US Forest Service Region 10 (USDA); 2 – David Albert, The Nature Conservancy, Juneau, AK; 3- US Fish and Wildlife Service (USDI); 4 – Alaska Department of Fish and Game, State of Alaska; TLMP – Tongass Land Management Plan (2003 SEIS); AWC – Anadromous Waters Catalog, Southeastern Region.

Table 3.1 (cont.) GIS data sources

Group	Description	Units	Method	Data/Source
Freshwater/streams		meters		
	Alluvial		all channel types	SE_STRMS [5]
	Beaver Dam		n.a.	""
	Estuary		n.a.	""
	Flood Plain		all channel types	""
	Glacial		n.a.	""
	High Gradient		all channel types	""
	Ice		n.a.	""
	Limnic		n.a.	""
	Low Gradient		all channel types	""
	Moderate Gradient		""	""
	Palustrine		""	""
	Riverine		""	""
	Slough		n.a.	""
	Unclassified		n.a.	""
Wetlands		acres		
	Subtidal estuary		all substrates	NWI [5]
	Intertidal estuary		all substrates	""
	Limnetic (Lake)		n.a.	""
	Lattorial (Stream)		all substrates	""
	Subtidal marine		n.a.	""
	Intertidal marine		n.a.	""
	Palustrine (bogs/muskegs)		all substrates	""
	Tidal riverine		n.a.	""
	Lower riverine		""	""
	Upper riverine		""	""

Key: 5 - US Geological Service (USDI), NWI - National Wetlands Inventory

Table 3.1. (cont.) GIS data sources

Group	Description	Units	Method	Data/Source
Hunting		watershed ranks		
	Juneau deer harvest		by VCU or GMU	TRA [4]
	Ketchikan deer harvest		""	""
	Brown bear harvest		""	""
	Black bear harvest		""	""
Fisheries		watershed ranks		
	Primary salmon		upper 20% of salmon VCUs	TRA [4]
	Secondary Salmon		lower 80% of salmon VCUs	""
	Sportfishing		user density	""
Other				
	Roads	km	total length by VCU	TNF_ROADS [1]
	Recreation Sites	# sites	n.a.	REC_SITES [1]
	Log Transfer Sites	# sites	n.a.	LTF [1]

Key: 1- SE Alaska GIS Library, US Forest Service, Region 10 (USDA); 4 - Alaska Dept. of Fish and Game; VCU - Value Comparison Unit (approximates watershed units), GMU - Game Management Unit (one or more watersheds); TRA - Tongass Resource Assessment (1998)

Table 3.2. Summary of 'Alaska lands' bills introduced in the US Congress during 1975-80. House (HR) and Senate (S) bills were coded as pro- or anti-conservation or neutral (bipartisan) based on text and sponsoring legislators.

	1979-80		1978-79		1977-78		1975-76		1975-1980		
	HR	S	HR	S	HR	S	HR	S	HR	S	Total
Pro	5	1	9	3	5	0	5	0	24	4	28
Con	4	0	2	4	1	3	1	3	8	10	18
Neutral	0	1	3	4	0	1	0	1	3	7	10

Table 3.3. Conservation units designated and provisions in HR 39 during the legislative process in 1979-80 (96th Congress). Total number of conservation units included in each version/amendment is shown below. Provisions in sections of HR 39 pertaining to the Tongass National Forest (Title IV – National Forest; Title VI – National Wilderness System), were coded based on subject matter of text.

		Provisions (n)					
	Units (n)	Timber	Fisheries	Recreation	Subsistence	Native claims	Mining
Introduced	16	7	2	2	1	4	0
House amended I	13	5	0	0	1	1	1
House amended II	13	5	1	0	1	1	1
House passed	16	9	1	2	1	6	2
Senate amended	15	3	2	0	0	2	4
Senate passed	14	5	3	2	0	5	9

Figure 3.1. Map of southeastern Alaska, Tongass National Forest boundaries and wilderness reserves (Wilderness and National Monuments).

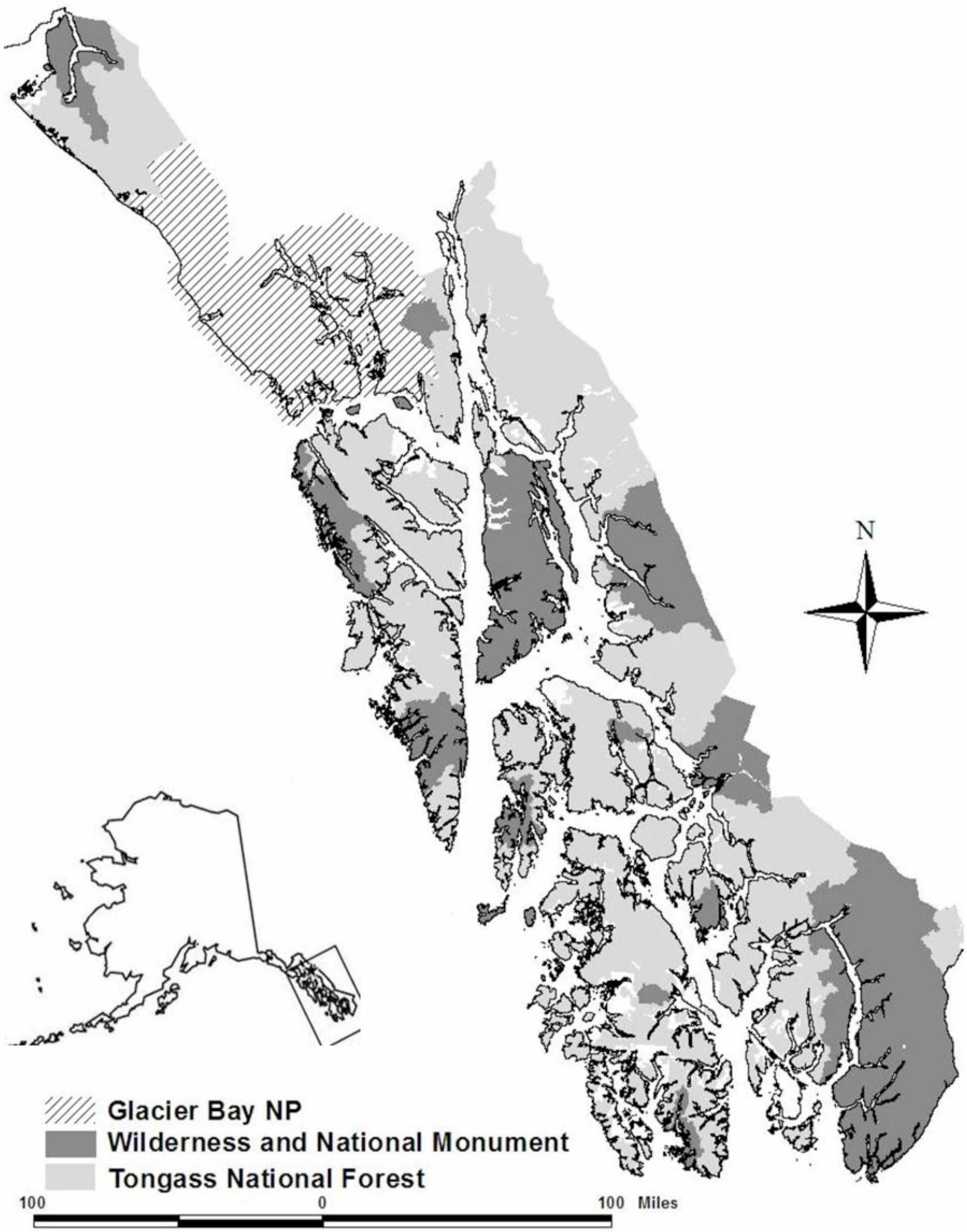

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Figure 3.2. Average percent representation of Tongass wilderness reserves among landcover, forest, freshwater, wildlife habitat, salmon stream and wetland types in the Tongass NF. See Table 3.1 for variables in each group.

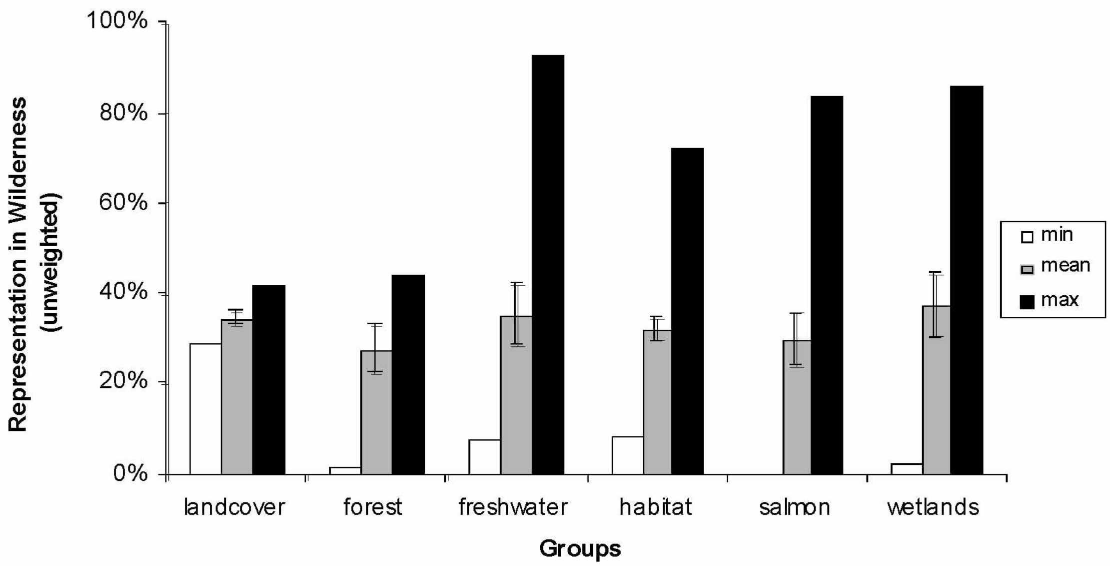


Figure 3.3 (a). Comparison of representation of landcover, forest types, and core ecological areas in wilderness and non-wilderness Tongass lands, based on area-weighted ratios.

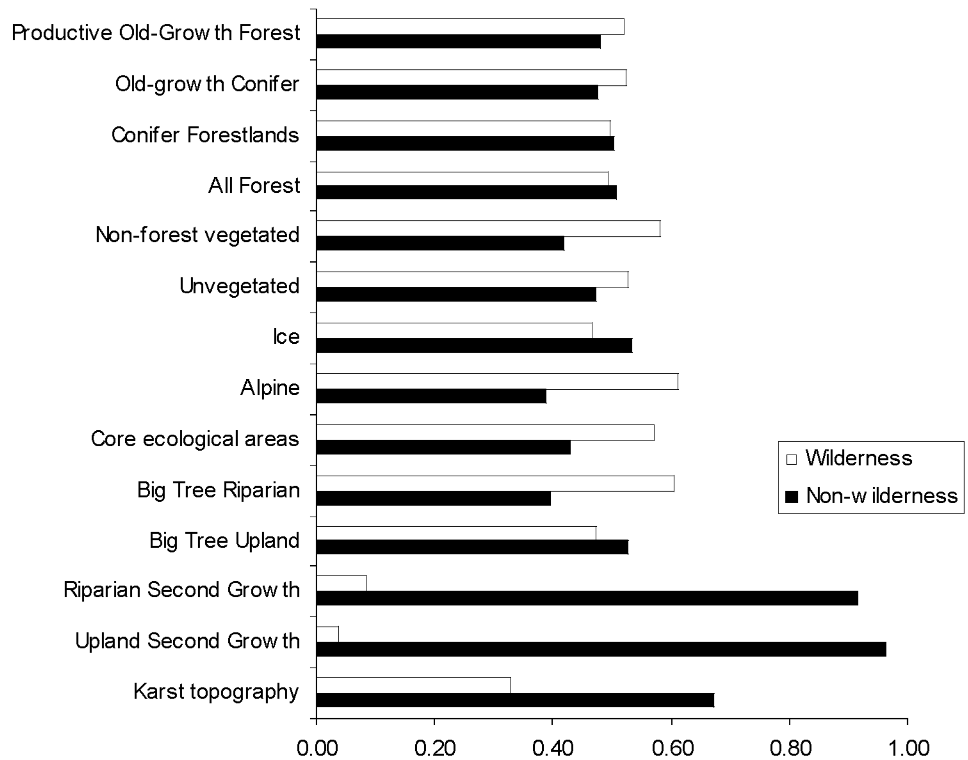


Figure 3.3 (b). Comparison of representation of stream types in wilderness and non-wilderness Tongass lands, based on area-weighted ratios.

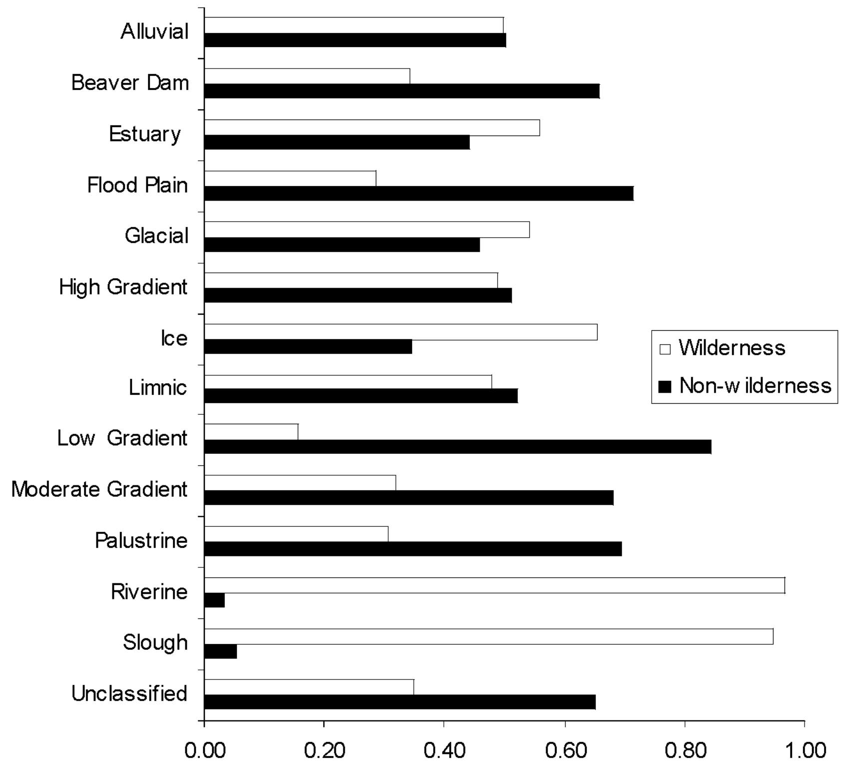


Figure 3.3 (c). Comparison of representation of mapped aquatic habitat for Pacific salmon in wilderness and non-wilderness Tongass lands, based on area-weighted ratios. Five primary species are included below.

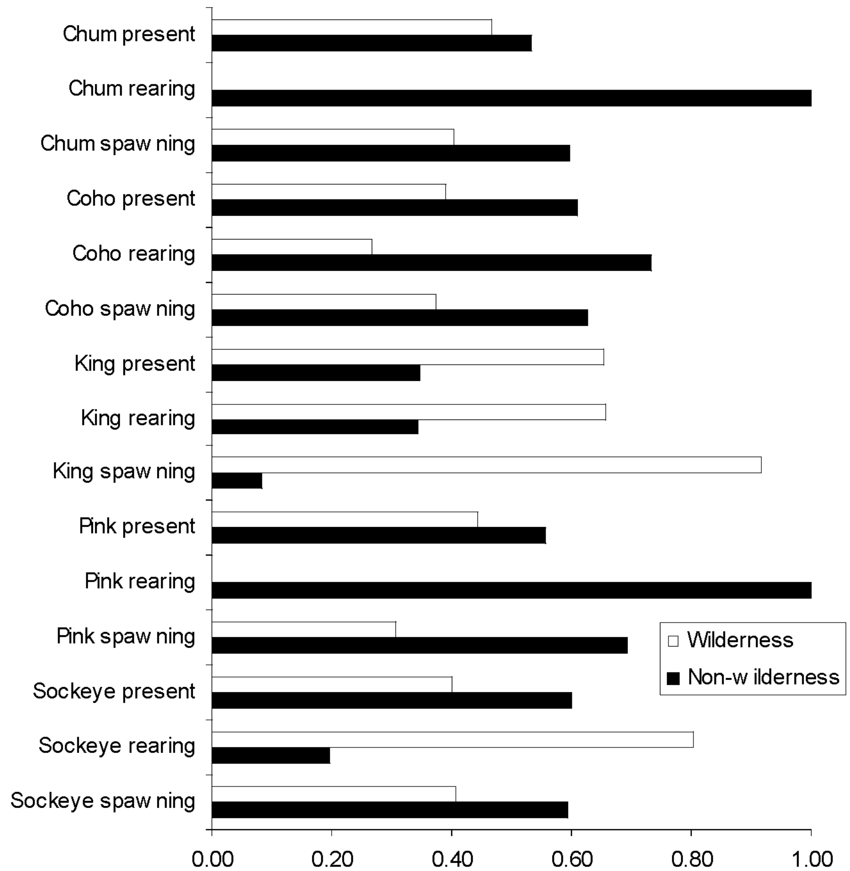


Figure 3.3 (d). Comparison of representation of wetland types in wilderness and non-wilderness Tongass lands, based on area-weighted ratios.

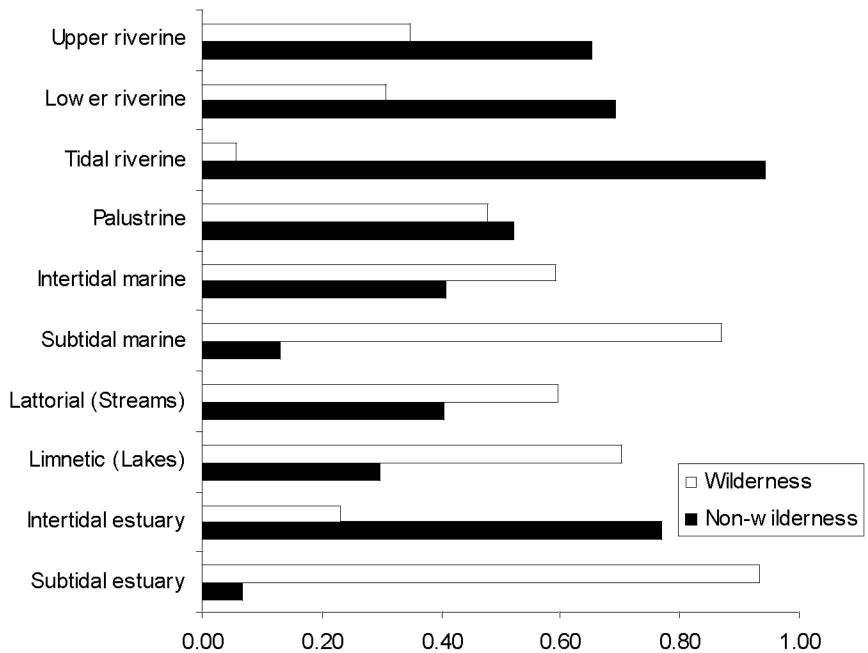


Figure 3.3 (e). Comparison of representation of endemic and migratory species habitats in wilderness and non-wilderness Tongass lands, based on area-weighted ratios.

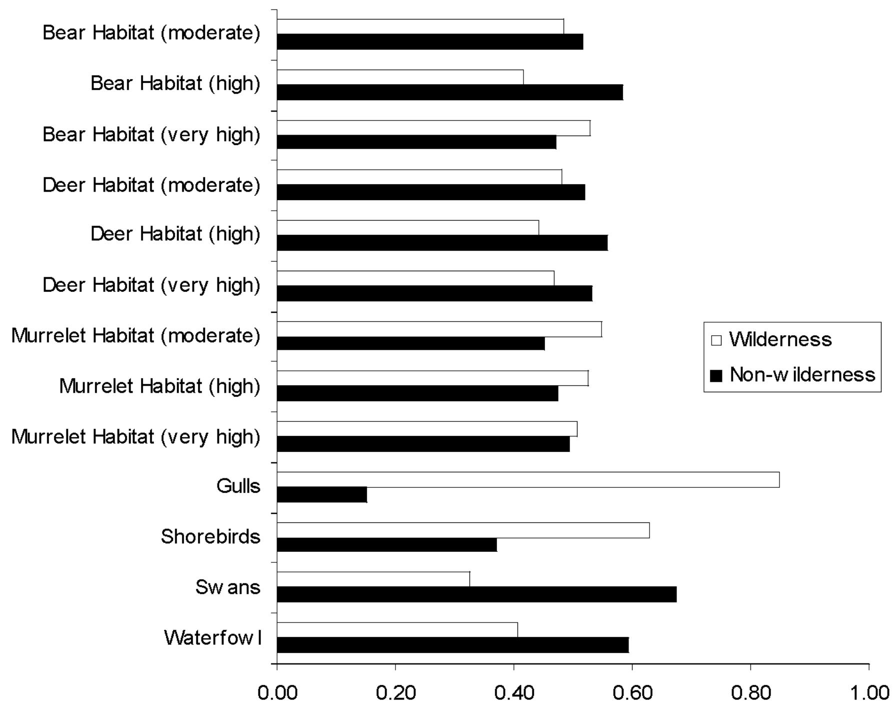


Figure 3.4. Comparison of representation of social variables in wilderness and non-wilderness Tongass lands, by area-weighted ratios.

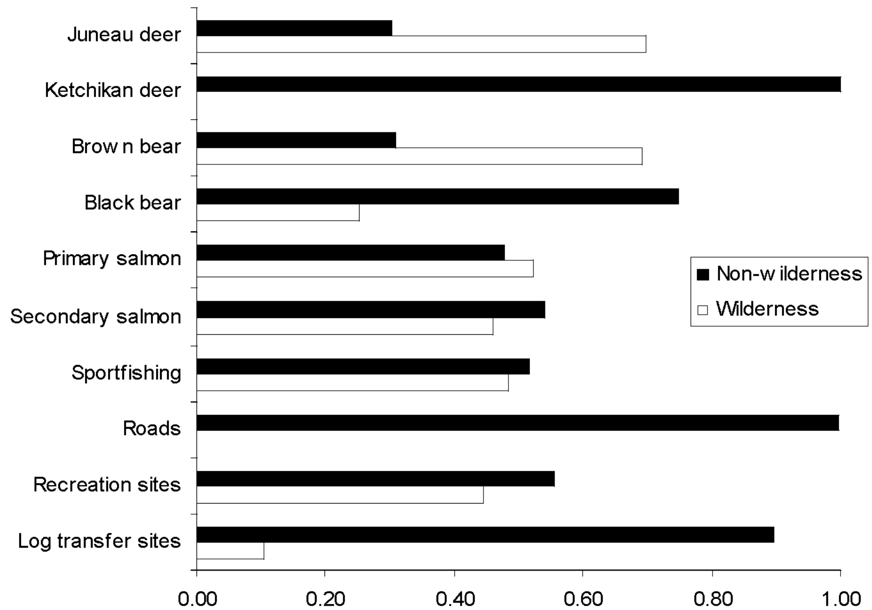
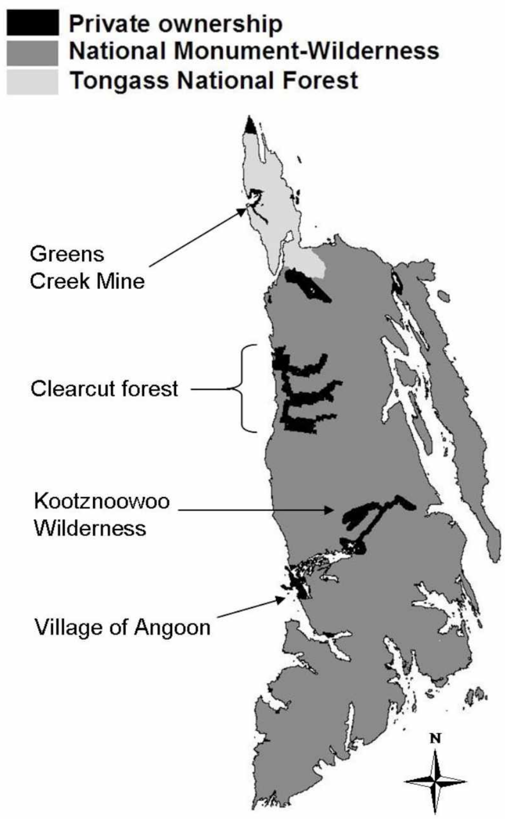


Figure 3.5. Map of Admiralty Island (surrounding areas are not shown).



Appendix 3.1. Annotated summary of bills and resolutions introduced during the 96th Congress (1979-80) pertaining to Alaska lands, grouped by coalition.

Bill	Sponsor	Last Major Action / Committee

Pro-conservation

HR 39 — Udall — Public Law 96-487 (1980)
- House version of the Act, was amended in conference twice, reported to Senate, amended once, passed by joint resolution and signed by President Carter

HR 2219 — Murphy — Referred to Merchant Marine and Fisheries

HR 3636 — Udall — Referred to Merchant Marine and Fisheries
- several timber provisions, including modifying long-term contracts to replace timber units designated as wilderness, improving production through thinning, loan program for equipment to improve utilization, study on ways to increase timber yields, improve efficiency; replaces timber lands removed from Native selections, but excludes Admiralty Island; establishes Admiralty and Misty Fjords monuments, grandfather clause for dwellings/campsites in national monuments (permits may last ten years after Act); maintenance of public use cabins, limits new cabins

HR 3651 — Udall — Referred to Merchant Marine and Fisheries
- more Native timber land exchange provisions, requires water quality regulations for mining activities on NF land

HR 8311 — Udall — Referred to Merchant Marine and Fisheries
- amends HR 39 with strong pro-conservation measures, increases acreage of wilderness areas, designates additional planning areas on the Tongass where timber harvest and mining is prohibited (LUD II), mentions roadless area review, requires Tongass timber program funding to be drawn from federal oil, gas, timber and coal receipts, limits mining in Quartz Hill to current rights, permits local residents to file civil actions related to subsistence; compromises include protection of valid leases of homesites, limits executive withdrawals of no more than 5000 acres without joint approval of Congress within one year

S 222 — Durkin — Referred to Energy and Natural Resources
- permits fishery research, management, enhancement and restoration in wilderness to ensure fish production in the Tongass; existing public use cabins subjected to regulations to preserve wilderness character, permits commercial fishing in wilderness

Anti-conservation

HR 2199 — Huckaby — Referred to Merchant Marine and Fisheries
- designates Tongass special management areas, with ten-year timber moratorium that may be waived to maintain supply to dependent industry, establishes National Forest Timber Utilization Program and appropriates National Forest Fund receipts, closes game harvest in monuments for purposes other than subsistence

HR 5662 — Young — Referred to Interior and Insular Affairs
- Western Lands Distribution Act of 1979: claims federal land ownership in western US states impinges on state sovereignty, requires transfer of many types of federal land to states, establishes Federal Land Transfer Board, requires state to form State Land Commissions, has Alaska-specific provisions for transferring lands

HR 6257 — Weaver — Vetoed by President Carter
- authorizes sale and exchange of National Forest lands not within protected designations

HR 7837 — Santini — Referred to Interior and Insular Affairs
- Western Lands Distribution and Regional Equalization Act, similar to HR 5662 (Young)

Bipartisan

S 9 — Jackson — Referred to Energy and Natural Resources
- introduces text from HR 2199 (Huckaby), related to Tongass special management areas, National Forest Timber Utilization Program, etc.

Appendix 3.2. Annotated summary of bills and resolutions introduced during the 95th Congress (1978-79) pertaining to Alaska lands, grouped by coalition.

Bill	Sponsor	Last Major Action / Committee
Pro-conservation		
HR 39	Udall	Amended, reported to Senate
- establishes titles for ANILCA, including Tongass wilderness and monuments, subsistence, ensuring timber supply, no mention of mining specifically		
HR 1652	Dingell	Referred to Merchant Marine and Fisheries
HR 1907	Udall	Referred to Interior and Insular Affairs
HR 1974	Udall	Referred to Interior and Insular Affairs
HR 10467	Meeds	Referred to Interior and Insular Affairs
HR 12625	Udall	Referred to Merchant Marine and Fisheries
HR 12703	Meeds	Referred to Merchant Marine and Fisheries
S 1332	Abourezk	Referred to Energy and Natural Resources
S 1500	Metcalf	Referred to Energy and Natural Resources
Anti-conservation		
HR 5505	Quillen	Referred to Interior and Insular Affairs
HR 11599	Holt	Referred to Interior and Insular Affairs
S RES 507	Gravel	Referred to Energy and Natural Resources
- procedural, holds lands until Congress acts		
S 1787	Stevens	Referred to Energy and Natural Resources
- establishes cooperative management among Fed, State, private (Alaska Land Classification Commission: inventory, land use planning, ensuring economic growth and well-being of AK residents		
S 2111	Gravel	Referred to Energy and Natural Resources
- changes appraisal system for stumpage rates on the Tongass		
S 2118	Gravel	Public Law 95-174
- authorizes conveyance of home sites on NF lands for lifetime occupancy		
S 2944	Gravel	Referred to Energy and Natural Resources
- establishes Federal-State Land Use Planning Commission, contains titles on subsistence, authorizes mineral exploration in all Alaska units (parks and monuments require congressional approval), preserves access and use rights for existing claims, gives joint planning commission authority to plan transportation/utility rights-of-way, sets a high standard for Secretary refusal of right-of-way plans, exempts AK BLM lands from wilderness studies		
Bipartisan		
HR 6564	Murphy	Referred to Merchant Marine and Fisheries
S 499	Jackson	Referred to Energy and Natural Resources
S 500	Jackson	Referred to Energy and Natural Resources
S 658	Hatfield	Passed House, amended
- procedural, holds lands for one year pending congressional action; prevents interference with timber sales and harvests under contract		
S 2465	Jackson	Referred to Energy and Natural Resources

Chapter 4

Dynamics of federal land management during the 20th century

4.1 Summary

This chapter provides an integrative understanding of the patterns of change in SE Alaska land management and the implications of these dynamics at multiple scales. I conducted a case study of timber management in the Tongass National Forest and its linkages with the SE Alaska economy, which was the dominant thrust of resource management on public lands in SE Alaska during the 20th century. Using a narrative format, this case study is grounded in complex systems theory to describe the cycle of creation, collapse and renewal related to boom-bust of the regional timber industry. Based on the longitudinal dynamics of a quantitative indicator (annual timber production from the Tongass), the history of Tongass management is segmented into phases of this 'adaptive cycle' to elucidate specific drivers of change and their impacts on land use planning, National Forest policy, and the growth and decline of the forest products economy. A timeline of important events in SE Alaska management is presented. From the systems perspective, the case study illustrates how cross-scale linkages and stabilizing structures eventually became rigid and maladaptive in the changing political and economic landscapes of the Tongass and the National Forest system in general. At different points in the Tongass history, the confluence of multiple positive and negative feedbacks drove the rapid (non-linear) changes associated with mobilization and decline of the timber industry. In SE Alaska, these feedbacks largely arose from the social dimension, e.g., policies, national public opinion, and global timber markets. This finding differs from most studies of similar 'pathologies' of resource management which have attributed cycles of collapse and renewal to ecological feedbacks arising from degradation of ecological processes and resilience.

4.2 Introduction

In 1908, the Tongass National Forest was established by President Theodore Roosevelt to encompass the vast majority of the southeastern region of the Alaska Territory. The first Tongass managers sought to convert old-growth forest into even-aged stands for sustained yield management; and to foster regional economic growth by supplying a regional timber industry (Rakestraw 1989). Based on an unprecedented long-term lease and subsidy structure authorized by Congress in 1947, a pulp-based SE Alaska timber industry was established based on a guaranteed supply of Tongass timber and favorable market conditions. For the next fifty years, Tongass timber was harvested and locally processed under a subsidized long-term lease structure. Harvest outputs peaked in 1970 and the vast majority of SE Alaskan forest products were exported to Asian markets. By 1997, a number of factors (including environmental policies, institutional reforms, judicial decisions, and market downturns) prompted the premature termination of the two long-term contracts that supplied much of the regional industry. Since these events, Tongass timber outputs have declined to the levels of the period prior to industrial pulp production. Today, Forest Service managers must negotiate a highly complex, contentious, and litigious planning process to conduct timber management activities. The regional industry operates well below its capacity, despite the availability of Tongass timber and recent improvements in local technology and global market conditions.

At first glance, the 'boom-bust' Tongass story can be framed in relatively simple terms. When it was founded, the SE Alaska timber industry was based on subsidized access to a locally available resource that was in high demand at favorable market prices. When the subsidy was removed and timber markets became less favorable for SE Alaskan forest products, the industry collapsed. This abridged account, although accurate, does not provide much insight on how or why these events occurred. What were the *a priori* motivations for creating a timber industry in SE Alaska? How was this approach justified from the political and management perspectives? Who were the key actors in the founding of the industry and its associated management regime on the Tongass? How did they cooperate to implement the desired outcomes and protect these outcomes from external drivers of change? In subsequent years, how did these drivers of change, as well as local, national and global events, foster a new set of conditions in which the industry collapsed? Why and how did change occur in Tongass policy and management that led to removal of the timber subsidy and closure of the regional pulp mills? How does the current status of the industry and Tongass governance reflect both the founding and destabilizing forces of the last century? These questions are central to understanding how the federal management regime and timber economy of SE Alaska experienced change. They also provide a broader perspective on the role of resource management in the resilience of social-ecological systems in changing political and economic landscapes.

In this chapter, I applied systems theory to describe the multi-scale patterns of change in Tongass management and the regional timber economy during the 20th century. This perspective focuses on the 'federal land management system' as an organizing component and driver of change in the broader SE Alaska social-ecological system (SES), as defined in Chapter 1. I define the management system as a multi-scale pattern of resource use around which humans have organized themselves in a social structure (Walker et al. 2004). Like most complex systems (Holling et al. 1995; Light et al. 1995; Gunderson and Holling 2002; Peterson 2002) the SE Alaska management system has followed a pattern of change consistent with an adaptive cycle of creation, collapse, and renewal. The adaptive cycle describes how systems remain stable, reorganize, or transform in response to change, as well as how system interactions and feedbacks occur across scales. In this chapter, I used these concepts to frame a historical narrative of Tongass land management, with a focus on the drivers and dynamics that have fostered adaptive cycles at multiple scales. In the broader context of the dissertation, this narrative contributes to a functional understanding of the SE

Alaska social-ecological system and its dynamics in response to external forces of change.

4.3 Objectives

The purpose of this chapter was to provide an integrative understanding of the patterns of change in SE Alaska land management and the implications of these dynamics at multiple scales. I developed a case study of timber management in the Tongass National Forest and its linkages with the SE Alaska economy, which was the dominant thrust of land use planning and resource management in SE Alaska during the 20th century. I approached this case study using complex adaptive systems theory (Holling et al. 2002). A rationale for the application of the systems framework is provided, and the systems, scales, drivers of change, and cross-scale interactions of interest in this study are explicitly defined.

The majority of this chapter is a historical narrative of these systems framed in the adaptive cycle metaphor; e.g., a cycle in which a system is initiated (organization **[α]** phase), mobilizes (growth **[r]** phase), reaches a stable configuration (conservation **[K]** phase), and changes to a radically different structure (collapse-reorganization **[Ω-α]** phases). Overall, this narrative is an account of the synchronous rise and fall of the policy monopoly, the timber economy, and the dominant management regime associated with the Tongass National Forest. The story follows a complete 'loop' of the adaptive cycle of Tongass management, from creation of the Tongass in 1906, to the reorganization period of the present day. The narrative was developed with several goals in mind: 1) to provide an integrative and interdisciplinary history of system components and dynamics at multiple scales (e.g., institutions, economies, policies, ecosystems); 2) to show how system dynamics at multiple scales have followed a pattern of change consistent with the adaptive cycle; and 3) to describe the major drivers of change and their cumulative effects at various scales in the SE Alaska social-ecological system. Key policies, judicial decisions, and external events are identified as 'tipping points' between stages of the adaptive cycle. A timeline of important events in SE Alaska management is presented.

In the discussion, I address the importance of the policy subsystem in generating cross-scale feedbacks that either resisted or fostered change at different times in the adaptive cycle. The coupled dynamics of 'nested' policy and economic subsystems are discussed as potential factors driving the larger-scale dynamics of the SE Alaska management system. I show how cross-scale linkages and stabilizing structures eventually became rigid and maladaptive in the changing social, political, and economic landscapes of SE Alaska. I then evaluate the Tongass case with respect to the "pathology of natural resource management" described by Holling (1986) that has been commonly found in recent case studies of resource conflicts and economic boom-bust cycles (Redman 1999; Berkes and Folke 1999; Gunderson et al. 2002; Berkes et al. 2003; Walker et al. 2004).

4.4 Rationale

The management of the Tongass has historically been and remains one of the most controversial issues in US resource management history (Wilkinson 1997; Durbin 1999; Steen 2004; Nie 2006). This controversy is not unique to the Tongass, as noted by Wilkinson (1997), "the issue of timber harvesting in the national forests represents the single longest-running unresolved conflict in federal public land law and policy." However the Tongass is not the average US National Forest; it is by far the largest in area, comprising vast expanses of pristine and globally rare ecosystems including coastal temperate rainforests, glacial fjords and island archipelagoes. For this reason, SE Alaska and the Tongass have become a major focus of the global environmental movement and their opposition to development interests. Moreover, because of the dominance of the Tongass in land ownership of the region, nearly all decisions about land use and resources involve the Forest Service (Nie 2006). As a result, regional economic development as well as local community resilience have been, and continue to be, closely tied to Tongass management (Tromble 1996; Allen et al. 1998). For these reasons and others, e.g., the scale of industrial forestry practiced on the Tongass, the politics of U.S. national interests in Alaska, and growth of public opinion against clearcutting on public lands; the Tongass has become iconic of the broader controversy cited by Wilkinson (1997).

The boom-bust cycle of the timber industry is probably the most significant and well-documented outcome of Tongass policy and management in SE Alaska. Its history has been framed in a variety of ways, including: as a central theme in the history of the Forest Service in Alaska (Rakestraw 1989), as an egregious example of political influence, mismanagement, and corruption within a federal agency (Durbin 1999), as a 'damned complicated' situation by a former US Forest Service Chief (Steen 2004), as a local drama of lost jobs and livelihoods due to the 'economic vandalism' of environmentalists (Soderberg and DuRette 1988), and as a study of statutory and political governance leading to the current "deadlock" situation (Nie 2006). While each account yields valuable insight on the issue, each had its origins in disparate disciplinary and normative viewpoints. The failures of traditional disciplinary perspectives to capture the social-ecological interactions at multiple scales that contribute to resource conflicts and management crises are well documented (Gunderson et al. 1995; Holling et al. 2002; Berkes et al. 2003). For this reason, a synthesis is needed that brings together the ecological, socio-economic, and political facets of the Tongass story.

As described in Chapter 1, complex adaptive systems theory provides the integrative framework needed to bring together multiple disciplinary perspectives in a way that generates a functional understanding of interactions and patterns of change (Holling et al. 2002). Complex systems theory helps to explain the non-linear dynamics and multiple stable states that are commonly observed in ecological, economic, and political systems. When these social and natural systems and their multi-stable dynamics are integrated into a single social-ecological system (SES), the complexities and uncertainties associated with system behavior increase dramatically. To frame how SESs experience change, theorists have shown the most systems experience an adaptive cycle of creation, collapse, and renewal (Holling 1986; Holling et al. 1995; Gunderson et al. 1995; Berkes et al. 2003; Walker et al. 2004). By observing dynamics and adaptive cycles at multiple scales, we may learn how management crises occur, as well as how to predict and prevent them.

Based on the SE Alaska systems model in Chapter 1, I defined the regional SES in terms of a set of 'nested' systems existing at multiple scales (Figure 1). The focus of this case study is the federal land management system, its nested subsystems, and their adaptive cycles. I define the management system as the patterns of resource use around which humans have organized a particular social structure (Walker et al. 2004), which includes institutional, economic, and political components. The institutional component - the US Forest Service and Tongass administration - is considered an integral part of the larger management system. At a smaller scale, I defined the political and economic components as 'nested' within the larger-scale management system; e.g., the 'policy subsystem' that governs Tongass management and land use decision-making; and the 'economic subsystem' that defines the structure, capacity and efficiency of the regional industry and the market demand/value of its products. Both subsystems have components and drivers of change that are 'internal' to the system, e.g., the policies intended to specifically govern the Tongass, and the economic factors pertaining to local industry, and components/drivers that are 'external' to the system, e.g., the policies related to national environmental and administrative regulations, and the economic factors pertaining to global timber markets.

As a result, the dynamics of each subsystem are influenced by the interactions among internal and external drivers of change. These subsystem dynamics generate feedbacks at multiple scales, including the larger-scale management system of SE Alaska. To describe these dynamics and feedbacks across scales, I presumed that these systems followed an adaptive cycle, and that the coupling of cycles at smaller scales (e.g., policy and economic subsystems) could generate strong and transformative feedbacks at larger scales (e.g., federal management system). We can consider two or more adaptive cycles to be coupled when the cycles experience the same stages at similar points in time; this phenomenon is known as "hypercoherence" (Walker et al. 2004). Hypercoherence often drives transformative changes in larger-scale systems through strong feedbacks and the emergence of new system components and/or controls (Gunderson and Holling 2002). Thus we can observe larger-scale dynamics in terms of the smaller-scale components and patterns of change, which are often more easily observed and understood.

For these reasons, the following narrative frames the history of Tongass management (and its policy and economic components) in the four stages of the adaptive cycle: organization, growth, conservation, and collapse-reorganization. The narrative follows these stages based on the longitudinal dynamics of a key indicator variable: the annual timber harvest volume from the Tongass NF (1910-2005). The narrative is based largely on two of the sources described above: the history of the U.S. Forest Service in Alaska (Rakestraw 1989) and the recent study of Tongass statutory and political governance (Nie 2006).

4.5 Organization phase [α] 1908-1947

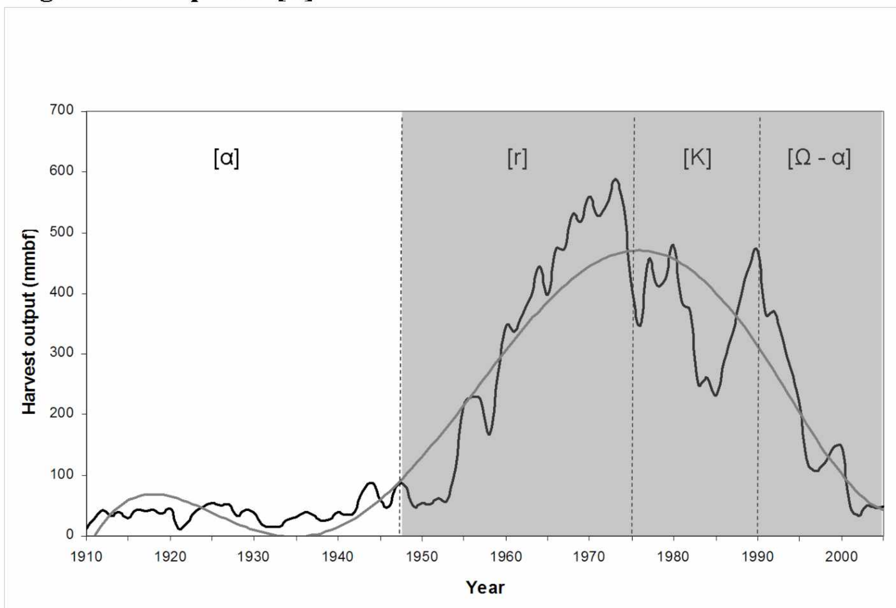


Figure 4.1. Organization stage [α] of Tongass management from 1908-1947. Based on harvests 1910-2005; the entire period is divided into four discrete stages of the adaptive cycle. Black line is annual harvest data; the gray line is a fifth-degree polynomial fit (for illustrative purposes).

"…none of the ordinary ranger duties of those officers in the states… no road or trail building, no fire patrol nor fire fighting, and no [live] stock to look after…chief duties are to sell timber, scale logs, and report on mining claims."

- 1906 report to Forest Service Chief Gifford Pinchot on the newly established Alexander Archipelago Forest Reserve in Southeast Alaska (Rakestraw 1989)

"About 95% of the commercial forest land of southeastern Alaska is occupied by over-mature stands of hemlock, spruce and cedar… these decadent stands should be removed by clear-cutting methods as soon as possible to make way for new stands of fast growing second growth timber."

- 1964 Multiple Use Management Plan for the Alaska Region, USFS (Nie 2006)

During the 19th century, forests in SE Alaska were harvested only for local use, primarily to support fur traders, the salmon industry, and soon after the turn of the century, the Gold Rush (Naske and Slotnick 1987). In the first half of the 20th century, the foundational elements of the Tongass timber program and management policy emerged as an 'organization' stage of forest management. Using the analogy of forest succession, this 'pioneer' stage of early tree regeneration is when several interacting factors dictate how the resulting mature forest will be organized (e.g. structure and species composition). Likewise in SE Alaska, the coincident arrival of new players, new conditions, and new forces for change would dictate subsequent system development and structure.

The 6.7 million acre Tongass National Forest was established in 1908, five years after the creation of the Alexander Archipelago Forest Reserve in southeastern Alaska. Within a year, President Roosevelt and US Forest Service (USFS) founder Gifford Pinchot expanded the Tongass by an additional 8.7 million acres. From its earliest beginnings, Tongass managers were the 'pioneers' of the broad vision of encouraging regional population growth by developing a strong, self-sufficient economy based on timber harvest (Rakestraw 1989; Nie 2006). During this period the USFS had both the natural capital (land base) and the social capital (legal authority) to implement this vision. The roots of the ultimate Tongass approach – to convert old-growth stands to 'manageable' second-growth forests, while fueling a forest products industry based on pulp and sawtimber – were evident in the initial USFS inspections in 1908-1912. In 1909, upon completion of the first timber inventory, Tongass officials suggested that pulp production was the best use of the Forest and recommended revision of federal law to allow the sale of USFS lands for business purposes. Early Tongass officials informed their superiors that "the chief need is for a planned harvest of the mature timber" (Rakestraw 1989). In summary, the organizational phase of Tongass timber policy grew out of a local and national vision - a new mental model - of the role of forestry in an expanding economy. Southeastern Alaska provided the conditions to implement this vision at a grand scale.

The industrial approach required significant outside investment to establish the sufficient economy of scale to make SE Alaska timber profitable. Despite the pursuit of these investments by key figures; e.g., USFS Chief William Greeley in the 1920s, and Alaska Regional Forester F. E. Heintzleman throughout the 1930s and 1940s, these efforts were thwarted by factors such as the Great Depression, high transportation costs, and a poor regional economic climate. During this period, harvest of Tongass timber was largely done by individuals or small companies seeking to fulfill local demand. Tongass harvests provided 90% of locally-used wood products by 1925 (Rakestraw 1989). In 1933, for the first time in history, a mill in SE Alaska (in Ketchikan) established a market in Seattle for high-grade 'clear' Sitka spruce. This entry into the larger US market indicated a potential comparative advantage for Alaskan timber, and established a cross-scale linkage that strongly influenced future forestry development.

World War II served as the catalyst to implement visions of larger-scale development of the Tongass, because US wartime demand for airplane lumber exceeded supplies in Oregon and Washington that had been depleted during the First World War. Regional Forester Heintzleman sought the advice of timber magnates in presenting his case for what became the Alaska Spruce Log Program (ASLP). Created as an agency in 1942, ASLP supplied 'Lower 48' mills with high-grade Sitka spruce from the Tongass. At the time, logging occurred primarily by high-grading the best trees in accessible sites, such as beach fringes and river bottoms. However, the collective opinion of Tongass managers, many of whom were professionally trained foresters, was that clearcutting was a superior method (Taylor 1935; Rakestraw 1989). Despite the lack of experimental comparisons with other silvicultural treatments, Taylor's (1935) seminal Ecology article was the primary scientific justification for a switch from high-grading to clearcutting in SE Alaska. Tongass manager C.M Archbold, working under Heintzleman to direct the ASLP, shifted the silvicultural prescription to clearcutting and demonstrated the value of harvesting low-grade materials.

In the 18 months of ASLP's existence, Archbold oversaw the export of 38.5 million board-feet (mmbf) of high grade spruce to 'Lower 48' mills and the transfer of 46 mmbf of lower (utility) grade material to local SE Alaska mills. For reference, the agency's legislated target was 100 mmbf of high grade spruce per year, with no mention of low-grade materials (Rakestraw 1989). While short-lived, the wartime program demonstrated the commercial viability of both sawtimber and utility-grade materials from SE Alaska. It also forged stronger relationships among Tongass officials, national policy-makers, and timber industry representatives (Rakestraw 1989) and precipitated a shift to a new management regime: clearcutting for industrial pulp production, supplemented by lesser volumes of sawtimber.

In summary, this organizational stage of the Tongass adaptive cycle is highlighted by the emergence of several factors that would shape the system's future configuration. First, the rise to dominance of a new mental model of Alaskan forestry - one in which industrial production would support both management and economic goals - was driven by national figures, such as Roosevelt, Pinchot and Greeley, as well as local authorities, such as Langille, Olmstead, Heintzleman and Archbold. Pinchot, the founder and braintrust of the Forest Service, made the business of forestry a central tenet of its institutional philosophy:

> "…the whole work of the [USFS] is intentionally based on perfectly clear-cut business principles. We advocate nothing in the way of forestry that will not pay. We do not ask a man to practice forestry for any other reason than that it is good business policy." (as quoted in Wolf 1989)

The irony of this statement becomes apparent in light of the subsequent outcomes of subsidized industrial forestry in SE Alaska; however, at the time there was very little doubt of the benefits of industrial forestry and the requisite role of the Tongass in the region. The concept reached across scales, as it became linked to the war effort, post-war reconstruction, and the Alaskan statehood movement (Nie 2006).

A second organizing principle that emerged during this time was the 'maximum sustained yield' (MSY) approach to timber production, adopted by the USFS and legitimized by the Sustained Yield Forest Management Act of 1944. This approach required an even-aged forest management regime and emphasized the clearcut method as the most efficient harvesting practice. In the largely pristine, old-growth forests of the Tongass, the formal adoption of MSY principles meant that both high and low grade timber would be harvested to achieve even-aged second growth stands. This school of thought also viewed old-growth forests as 'decadent' or 'decrepit' and instilled a strong rational foundation for timbering in the vast old-growth stands across SE Alaska (Rakestraw 1989). To this end, Tongass managers facilitated the shift from a high-grading method to a clearcutting method. As I discussed above, this social learning was supported by contemporary ecological research (Taylor 1935).

Third, the emergence of SE Alaskan timber in 'Lower 48' markets (via local mills in 1933, and later the Alaska Spruce Log Program) provided an essential economic justification for clearcutting and MSY management of the Tongass. Key figures like Heintzleman and Archbold knew that outside investment in a SE Alaska timber industry hinged on demonstrating the value of the lower grade component of the Tongass timber base (Rakestraw 1989). Under the auspices of ASLP, they shifted to clearcutting, and the program subsequently yielded more low-grade timber than high-grade spruce. Tongass managers also showed that lower-grade materials could be processed locally at a profit.

Lastly, external drivers of change shaped the organization stage of Tongass management. For several decades, the vision of a pulp-based timber industry was infeasible despite vigorous efforts to attract outside investment. At various times, prospective investors were wary of high logistical costs, low timber value, export restrictions and a depressed economy (Rakestraw 1989). In time, World War II would trigger a rapid mobilization of industrial-scale forestry in the Tongass, via both the ASLP program (setting into motion the shifts described above) and the global timber demand of post-war reconstruction.

4.6 Growth phase [r] 1947-1975

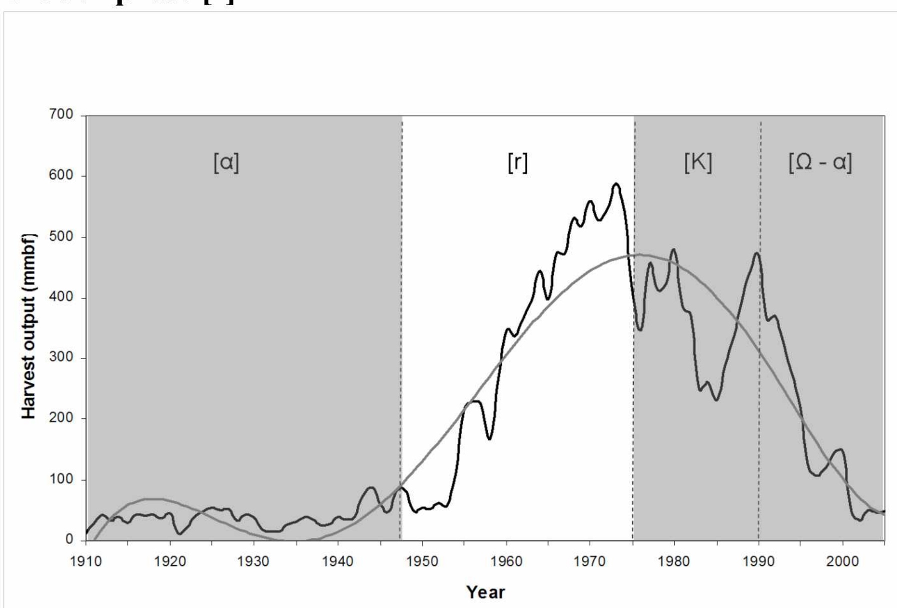


Figure 4.2. Growth stage [r] of Tongass management from 1947-1975.

"The pulp mill was the fruition of long standing dreams. The mill was a major triumph for Ketchikan." (Rakestraw 1989)

"Weathering the well-known boom and bust cycles of the pulp market is hard enough with a reliable pulpwood supply on private land… to recoup your investment on [public] land you need a raw material supply guarantee long enough and secure enough to deflect the fickle fingers of political football players. Fifty years is the magic number and a legal contract is the magic instrument. If the people of the Tongass were to have a business base, the Feds had to act in a businesslike manner." (Soderberg and DuRette 1988)

The passage of the Tongass Timber Act in 1947 (TTA), which authorized the creation of long-term timber contracts and pulp mills in SE Alaska, signaled the transition of the Tongass timber subsystem into the growth stage. The Act legitimized the long desired transformation of Tongass timber management from small-scale high-grading into large-scale clearcutting for industrial pulp production. Tongass officials now held a federally mandated blueprint and the discretional authority to mobilize the resources and expertise required to make 'Big Pulp' a reality in SE Alaska. In the analogy of forest succession, the 'exploitation' stage involves the rapid maturation of system structure characterized by vigorous growth, rapid accumulation of natural capital in biomass, and structural changes that alter the competitive balance among system components. Under USFS direction during this period, the importance and efficiency of the Tongass timber program (and the regional industry it supplied) grew steadily. By prescribing industrial-scale timber harvesting for the Tongass and legitimizing the long-term contract and other subsidies needed to encourage private investment, the TTA provided the competitive advantage needed to establish a timber industry in the difficult economic climate of SE Alaska.

The provisions of TTA were largely framed by Tongass officials, pro-timber lawmakers, and timber industry executives (Nie 2006). In fact, Tongass officials were already in negotiations with prospective long-term contract bidders when the TTA was passed (Rakestraw 1989). The legislation galvanized the already close linkages among agency, legislative, and private industry actors (Rakestraw 1989; Nie 2006), forming what can be characterized as a 'policy monopoly' (Kingdon 1995; True et al. 1999) of Tongass timber management. The Tongass policy monopoly achieved subsidies without precedent in USFS history: the authorization of fifty-year leases that guaranteed non-competitive access to billions of board-feet of publicly-owned, virgin timber (Repetto 1988; Wilkinson 1992). Leaseholders operated on a separate scaling system (for measuring and pricing volume) and had a proportion of their logistical costs refunded as purchased road credits. Harvest units were planned in close consultation with company foresters and then released to the leaseholders based on their current needs. Because these transactions involved the proprietary and fiscal operations of private corporations, they were kept confidential (Durbin 1999). Accurate record-keeping of long-term contract transactions, containing information suitable for public release, did not begin until the 1970s. Moreover, the USFS planning process was relatively unfettered by legislative complications, public participation or judicial decisions (Nie 2006). As a result there was a low level of transparency and a high level of internal control in the long-term contracts; features typical of subsidized industry regulated by a policy monopoly (Repetto 1988).

In addition to maintaining control over the venues of decision-making (in Congress) and planning (in the USFS), the Tongass policy monopoly was successful in politically defining the ‘problem’ and ‘solution’ (*sensu* Kingdon 1995) for SE Alaska. These actors shared a core set of beliefs and perceptions regarding the social and ecological conditions of SE Alaska, e.g., the need for a regional economic base to support regional growth and the Alaska statehood movement (Nie 2006), and the undesirable old-growth condition of the Tongass timber base (Rakestraw 1989). These beliefs defined the ‘problems’ that had been discussed on the Tongass since its creation, for which a ‘solution’ was devised many years prior to its codification in the TTA. This solution was the implementation of a production forestry regime in SE Alaska, much like the arrangement in other National Forests of the US Pacific Northwest (Trosper 2003). It was well suited for the scientific, management, and socio-political objectives of the time. In order to implement sustained yield forestry, there needed to be a destination for the lower quality material that constituted a large proportion of the Tongass timber base, hence the need for industrial pulp mills and associated 'feeder' sawmills. The economic base provided by these mills would support local communities and facilitate infrastructure as well as population growth. In short, a continuous supply of timber - managed by sustained yield principles and processed locally - became closely tied to the goal of community stability and further settlement in SE Alaska. Moreover, a successful timber industry in SE Alaska supported the image of an economically viable US state, instead of a federally-dependent 'satellite' territory used primarily for national defense (Rakestraw 1989; Nie 2006).

Early in this period, the Tongass mobilized rapidly in the direction prescribed and afforded by its policy monopoly. Less than six months after passage of TTA, the USFS and the newly formed Ketchikan Pulp Company (KPC) agreed to the preliminary terms of a lease contract. The contract was finalized in 1951 and guaranteed KPC over 8.5 billion board-feet of timber over 50 years, subject to periodic five-year review by the USFS. The contract set aside nearly one-fifth of the Tongass for KPC's exclusive bidding rights (Soderberg and DuRette 1988). One year later, a group of Japanese investors visited SE Alaska seeking an export pulp mill and sawmill. The initial post-war efforts of Japanese investors to enter SE Alaska were refuted; yet the rebuilding nation faced a massive timber and pulp deficit - and thus represented a major source of demand - and the passage of TTA provided the basis for cooperation. By 1953, the Japanese-owned Alaska Pulp Development Co. was incorporated in the US, and had agreed to a fifty-year, 4.5 billion board-foot contract requiring construction of a large sawmill and pulp mill in Sitka. By 1959, the Alaska Pulp Company (APC) was in operation in Sitka. A third long-term contract, of lesser size and duration than the KPC and APC sales, was finalized with the construction of a large sawmill in Wrangell by the Pacific Northwest Timber Co (PNTC).

In 1953, Regional Forester Heintzleman retired from the USFS and was appointed Territorial Governor of Alaska by President Eisenhower. Heintzleman continued his vigorous support for the SE Alaska timber industry, using his office to promote the creation of progressively larger long-term leases in the region (Rakestraw 1989). Several of these included offerings of massive volumes (up to 8.7 billion board-feet) in some of the most biologically rich areas of SE Alaska (e.g., one lease, upon completion, would have logged nearly 95% of Admiralty Island). While only three long-term contracts were signed, the persistence of Tongass officials (in preparing the offers) demonstrated the continued strength of the Tongass policy monopoly throughout the 1960s and into the early 1970s. The three existing long-term sales (KPC, APC and PNTC) comprised over ninety-percent of Tongass timber harvested during the 1960s and 1970s. In 1970, annual harvest from the Tongass peaked at 560 mmbf; the Alaskan share of US timber exports to Japan peaked at 42% in 1972; and the small city of Ketchikan prospered to become the third-largest producer of cellulose pulp in the world.

Yet during this period, several policy and judicial decisions began to create vulnerabilities in the Tongass policy monopoly, and by proxy, the SE Alaska timber industry. While these events appeared to have little immediate effect on Tongass timber outputs, they are significant because they set the stage for the weakening of the Tongass policy monopoly, and the subsequent dismantling of the long-term contracts four decades later. These initial 'perturbations' began to erode the statutory and discretional authority of the USFS by decentralizing the planning process and making it progressively more complex, and by challenging the Tongass policy monopoly's political supremacy by establishing new venues for debate, particularly in the judicial system.

From 1960-1975, these perturbations were mostly related to the growing influence of the broader environmental movement in the US. With the exception of one major lawsuit, these events were not specific to the Tongass or significantly detrimental to the harvest outputs of the timber program. First, the Multiple Use Sustained Yield

Act of 1960 (MUSYA) formally articulated the mission of USFS to include managing for “outdoor recreation, range, timber, watershed and wildlife and fish purposes.” Due to vague language regarding planning priorities and the appropriate scale and distribution of multiple uses, the mandate of MUSYA has been interpreted in many different ways and intensely debated[8]. The vague multiple-use mandate provided the basis for legal challenges to forest planning actions, from the ranger district to the national level (Rasband et al. 2004). MUSYA became a major challenge for an agency focused on the use of National Forests for timber production (Clary 1986).

The Wilderness Act of 1964 and the Administrative Procedures Act of 1966 further complicated the management mission and planning process of the USFS. Requiring all roadless public lands to be evaluated for potential wilderness designation, the Wilderness Act added another non-timber land use to the multiple-use mandate of the USFS. The Administrative Procedures Act (APA) enacted broad reforms on the bureaucratic procedures of all federal agencies. The legislation required greater transparency in the agency planning process and created the basis for agency decisions to be appealed by public stakeholders and private interest groups (Williams and Tolle 2001; Nie 2006). Prior to the APA many of these groups were denied the right to appeal because they could not demonstrate economic standing; i.e. that they would be directly affected by the agency decision. After APA, federal courts began to hear regularly appeals by environmental and stakeholder groups challenging USFS management decisions (Malmsheimer et al. 2004). As a result, the appeals process became one of the three primary venues (including litigation and public comment) of conflict resolution and communication between interests groups and the USFS (Nie 2006). Many of these actions were facilitated by the environmental assessments required by passage of the National Environmental Policy Act of 1969 (NEPA). Under NEPA, federal agencies were required to complete Environmental Impact

[8] In the Tongass, for example, MUSYA has been invoked to justify the offering of 8.7 billion board-feet of old-growth timber to single purchaser; and three decades later, the potential designation of 58 million acres of roadless areas as federally-protected Wilderness (Nie 2006).

Statements (EIS) for any actions that had potential environmental impacts. The EIS requirement provided fertile ground for legal challenges; since NEPA, more environmental lawsuits have been based on EIS requirements than any other federal statute (Rasband et al. 2004).

The first successful legal challenge to a major Tongass timber sale was filed in 1965, prior to the passage of NEPA and APA. While the initial ruling was in favor of the USFS, *Sierra Club v Hardin* used language from MUSYA, and later from NEPA, to delay and eventually block the completion of a massive pulp sale to the US Plywood Champion Co. The plaintiffs included local stakeholders who challenged the construction of a pulp mill in Echo Cove, north of Juneau. The construction of the mill (as in Ketchikan and Sitka) was a required part of the proposed long-term contract, and the several years of delay afforded by the Sierra Club lawsuit led to withdrawal of the sale in 1971. *Sierra Club v Hardin* was among the initial applications of NEPA to block a major agency decision, and the first time it was used to block a federal timber sale (Rakestraw 1989; Nie 2006). The cancellation of this sale foreshadowed the future of the Tongass timber program, in which appeals and lawsuits would obstruct timber harvest.

For the first few years after NEPA, aside from *Sierra Club v Hardin*, federal judges deferred to the discretional authority and professional expertise of the USFS. As the number of lawsuits based on NEPA grew throughout the 1970s and onward, this trend changed as environmental groups found more favorable venues in the federal judicial system (LeMaster 1984; Nie 2006). The adequacy and accuracy of the science used in the EIS process were often the basis for legal challenges, especially with respect to the practice of clearcutting in National Forests (Clary 1986). In 1972, the US Congress held extensive hearings on clearcutting as a timber management tool, largely due to growing public opinion opposing the management technique (Wilkinson 1992; Bliss 2000). Followed by the Endangered Species Act of 1973, the

USFS mandate was beset with additional environmental regulations and a major new venue for litigation. Lastly, the Freedom of Information Act of 1974 (FOIA) opened the planning process and management decisions to greater public and legal scrutiny.

In sum, the reforms created by NEPA, APA and FOIA were instrumental in opening up new venues for debate and decision-making that weakened the policy monopoly over Tongass timber management. Coupled with the vague multiple-use mandate of MUSYA, these reforms drove the transition of the Tongass policy monopoly towards a diffused decision-making setting, i.e., a configuration in which conservation interests were able to influence much of the decision-making process. In addition to the three components of the policy monopoly (Tongass managers, lawmakers/ political authorities, and representatives of private industry), three additional venues became major arenas for decision making and influence on Tongass governance: the federal judiciary, the USFS planning and appeals process, and environmentalist lawmakers in Congress (Nie 2006). This new configuration weakened the primacy of the Tongass policy monopoly as the influence of the three new elements grew steadily over the next several decades.

At the conclusion of the growth [r] stage, Tongass timber outputs had reached their peak and the Tongass policy monopoly had suffered only one major setback related to litigation. The mills in Ketchikan, Sitka and Wrangell prospered, and the regional industry supported an estimated 3500 local jobs (Tromble 1996). By this point, the Tongass timber program had converted hundreds of thousands of acres of old-growth forest to 'manageable' even-aged stands and supported a booming regional industry in the process. However, within twenty years the long-term lease contracts would be prematurely terminated, the Tongass timber base would shrink to one-third of its original size, and harvest outputs would collapse to pre-WWII levels. Between growth and collapse, the two intervening decades of resistance to change framed the 'conservation' stage of Tongass timber.

4.7 Conservation phase [K] 1975-1990

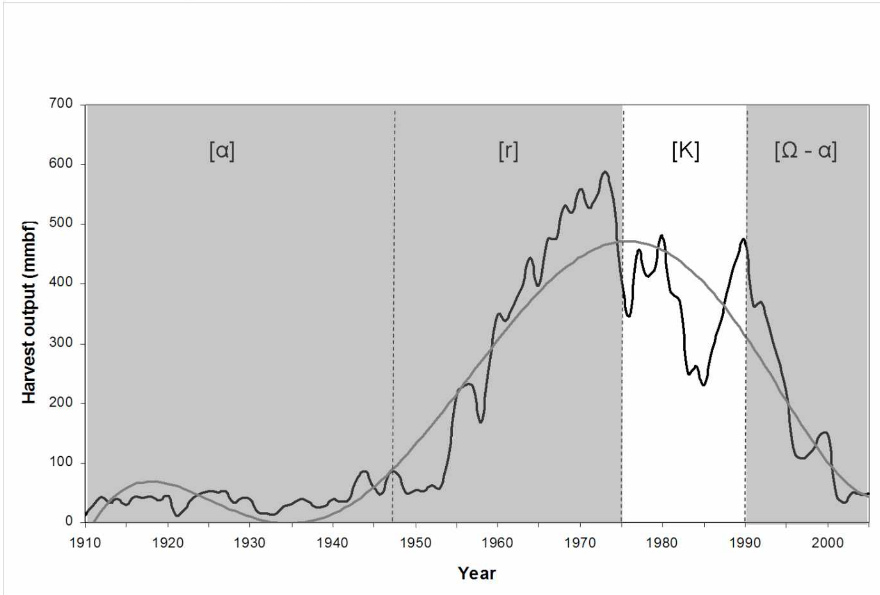


Figure 4.3. Conservation stage [K] of Tongass management from 1975-1990.

"It is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."

- Multiple Use Sustained Yield Act of 1960

"These laws are troublesome for both what they say and what they fail to say. In the past, Congress has promised more than it can deliver, be it big industry, subsistence resources, healthy runs of salmon, viable populations of wildlife, or genuine multiple use management…many of these conflicts are managed by the courts who must decipher sometimes baffling Congressional intent…by avoiding some of the most difficult choices, Congress delegated these decisions to the Forest Service." (Nie 2006)

During the ‘conservation’ stage in the history of the Tongass timber program, the established Tongass policy monopoly faced major drivers of change in public policy, public opinion and global market conditions. The interaction of these factors revealed the vulnerabilities, as well as the mechanisms providing stability and resilience, of key aspects of Tongass timber policy and the forest products economy it created in SE Alaska. The conservation stage is aptly named in two senses: first, it was a period in which the established regime sought to conserve its dominance in the face of external drivers of instability; second, it was a period of growing influence by the environmental conservation movement on USFS and Tongass policy and procedure. The former meaning is the focus of this section.

In this sense, from 1975-1997 the Tongass timber program (and its policy monopoly) resisted the policy reforms and shifts in public opinion that threatened its stability, but the system proved to be vulnerable to a confluence of these (and other) factors. Although the policy reforms of MUSYA, NEPA, and APA facilitated most of the legal challenges to Tongass management decisions from this point forward, it was language in the Organic Act that led to a 1975 court order that, for the first time, enjoined the USFS from clearcutting Tongass old-growth. This court order marked the beginning of the ‘conservation’ phase of Tongass timber management, in which its policy monopoly became mired in the diffused decision-making setting of environmental regulations, greater judicial scrutiny, and an increasingly contentious planning process. Despite these new conditions, the Tongass policy monopoly sought to maintain the configuration of industrial forestry in SE Alaska.

In anti-logging lawsuits brought against the Bitterroot NF in Montana and the Monongahela NF in West Virginia, federal judges ruled that clearcutting in National Forests was in violation of the intent and language of the Organic Act (Nie 2006). Immediately after these rulings, environmentalists filed suit to prevent further Tongass clearcut logging by the Ketchikan Pulp Co. and were temporarily successful

(*Zieske v Butz* 1975). This ruling was the first that directly challenged the legality of an existing Tongass long-term contract. By contrast, the 1965-71 Sierra Club v. Hardin action sought to prevent a pending sale by opposing its associated pulp mill on environmental grounds. *Zieske v Butz* set a powerful, albeit brief precedent against industrial-scale logging in the Tongass. The court-ordered moratorium on Tongass clearcutting put the USFS in the precarious situation of potentially defaulting on the long-term contracts upon which the regional industry depended. The Tongass decision, and those that preceded it, led to a deadlock that required immediate intervention by Congress.

The National Forest Management Act (NFMA), drafted in part to allow USFS managers to resume timber harvest operations in several National Forests, prescribed broad reforms to the USFS planning process. It addressed the clearcutting controversy by legitimizing the practice, establishing new nationwide guidelines for its use, and meanwhile instructing the USFS to "provide for diversity of plant and animal communities." Adding further to the complications and ambiguities created by prior legislation, NFMA required an interdisciplinary approach to planning and greater opportunities for public participation (Williams and Tolle 2001). NFMA also strongly reiterated the multiple-use mandate but, much like MUSYA, provided few specific prescriptions for its application. Moreover, NFMA did nothing to reduce the administrative discretion of the USFS in determining the distribution of land uses in achieving the multiple-use objective (Cheever 1997). As a result, Congress left the intent of NFMA open to debate, and effectively transferred the venue of that debate to the USFS administration and federal courts. In doing so, Congress facilitated the legal 'obstructionism' that has since become a major source of paralysis in National Forest planning (Williams and Tolle 2001; Steen 2004). Given the growing opposition to the long-term leases, the Tongass planning process eventually became one of the most contentious in the nation (Malmsheimer et al. 2004).

The NFMA also required each National Forest to complete a comprehensive multiple-use management plan, subject to revision every twenty years. The Tongass was first to complete its plan, which set an annual Allowable Sale Quantity (ASQ) at 450 mmbf (the plan dictated a maximum harvest of 4.5 billion board feet over ten years). Of this amount, 300 mmbf was guaranteed to long-term lease holders. Based on the remaining volume of guaranteed timber under contract (nearly five billion board-feet in total) and the lease duration, this amount was more than sufficient to meet contractual obligations on a sustained yield basis. The built-in overage in the Tongass ASQ was challenged by interest groups claiming that the Tongass Plan overemphasized timber production, and therefore violated the direction set by Congress in NFMA. Industry representatives felt the ASQ was too low to maintain current levels of private investment in the regional industry. In short, neither side was pleased; this quandary has plagued Tongass planning to the present day (Nie 2006).

Management of the Tongass was further complicated by the Alaska National Interest Lands Conservation Act of 1981 (ANILCA), which designated nearly one-third of Tongass lands as Wilderness and National Monuments. As a result, ANILCA reduced the available Tongass timber base by approximately one-third, and removed nearly all of Admiralty Island - where some of the most valuable remaining timber was located - from potential development. The Tongass was one of the most contentious issues in the ANILCA debate, due to vehement opposition by the Tongass policy monopoly (including USFS officials, Alaska lawmakers, and industry lobbyists) and local stakeholder groups. These actors viewed the federal withdrawal of Tongass lands from USFS management authority as a direct affront to the contractual agreements supporting the SE Alaska timber industry and, by proxy, viewed ANILCA land withdrawals as a direct threat to regional economic welfare (Nelson 2004).

In exchange for difficult compromises on wilderness designation in the Tongass, several of timber-related provisions were included. While the Tongass policy monopoly faced a series of legal challenges and policy setbacks during this period, it was able to safeguard its authority in the ANILCA debate. Among the many provisions negotiated into the bill by Sen. Ted Stevens, §705(a) authorized at least $40 million annually to support the Tongass timber program[9], which was instructed to supply the dependent regional industry at a rate of 4.5 billion bd-ft per decade (ratifying the ASQ set by the 1979 Forest Plan). Tongass managers interpreted this provision as a mandate to supply 450 mmbf per year regardless of market demand (Nie 2006). The funding also supported research for the improvement of forest yields, maximizing processing efficiency, and finding new markets for Tongass forest products. ANILCA also exempted the Tongass from NFMA guidelines requiring the USFS to remove unsuitable lands from the timber base. These provisions were largely contrary to the spirit of ANILCA (a conservation-oriented bill) and their inclusion demonstrated the persistent power of the Tongass policy monopoly in protecting their interests. Sen. Ted Stevens (R-AK) was instrumental in negotiating these provisions, which reaffirmed timber production as the dominant use of non-wilderness Tongass lands. For these reasons, the policy cycle was in a conservation stage because the Tongass policy monopoly and its primary structural element (the long-term leases) were resilient.

Soon after ANILCA, the vulnerability of the Tongass policy monopoly emerged as environmental interests gradually built the capacity to directly influence Tongass management at multiple scales; e.g., at the program scale, the use of NEPA appeals process to delay and cancel timber sales; at the institutional scale, the increased time and effort required to prepare environmental studies, navigate a complex planning

[9] Critics of the Tongass-specific provisions in ANILCA claim that this represented a direct subsidy to the local timber industry (Wilkinson 1992; Durbin 1999). By contrast, agency and timber-friendly historians emphasize that only $15 million of this allotment was designated for the timber program, and the remainder constituted the annual Tongass operating budget (Soderberg and DuRette 1988; Rakestraw 1989)

process, and deal with lawsuits; at the regional scale, the federal designation of wilderness and monument lands in SE Alaska, and the passage of the Tongass Timber Reform Act; and at the national scale, the passage of NEPA and other policies that complicated National Forest planning and created new decision-making venues in the federal courts. This pervasive cross-scale influence suggests that the political governance of the Tongass shifted from a monopoly (including only pro-development lawmakers, private industry and Tongass managers), to a more diffused decision-making setting (including pro-environment lawmakers, federal courts, and environmental groups). This shift indicated that the policy subsystem was entering the collapse phase of its adaptive cycle. The Tongass Timber Reform Act of 1990 (TTRA) was the likely 'tipping point' that reflected the loss of primacy by the long-standing policy monopoly.

In the economic subsystem, the first events that signaled the conservation phase of the cycle occurred several years prior to TTRA, when the business practices of the long-term lease holders came under attack in the federal courts. In a 1983 lawsuit, Reid Bros Logging v Ketchikan Pulp Co. claimed that KPC unfairly used the advantages afforded by USFS contracts to force smaller operators out of the regional industry. The court found that KPC had engaged in conspiracy and anti-competitive practices in violation of federal law and, in subsequent lawsuits, found that KPC and APC had colluded in these efforts to marginalize the smaller timber companies (Durbin 1999). These rulings did not immediately affect the long-term leases, but almost certainly contributed to the legislative rebuke of the lease structures codified several years later in the TTRA (Nie 2006).

The conservation phase of the economic cycle was also apparent in the dynamics of the regional industry in response to external market conditions. Beginning in 1979 the market conditions for Tongass timber exports experienced a dramatic decline throughout much of the 1980s, due mostly to fluctuation in global demand and increased competition (Rakestraw 1989). Tongass harvests declined in parallel with market fluctuations, suggesting that much of the regional industry was operating near the margin (Morse 1998). This high sensitivity to market downturns was not unique to the Tongass, but was significant because it revealed inherent vulnerabilities in the regional industry. First, the APC contract depended on the sustained levels of high Japanese demand for Tongass timber, even after post-war reconstruction had been completed. By 1985, due to a decline in the rayon market, the Tongass share of US timber exports to Japan dropped to its lowest point (6%) since APC began operations in Sitka. Second, because of the age and capital amortization of most SE Alaska mills, decisions about production levels for these facilities were largely driven by short-term profitability. Coupled with the high operating costs in SE Alaska, poor markets triggered sporadic mill closures and re-openings throughout the 1980s and 1990s (Morse 1998). Between 1984 and 1987, all of the major sawmills in SE Alaska - except those owned by KPC and APC - closed for at least a three year period; two of these mills would never reopen (Brackley et al. 2005). Lastly, the considerable subsidy afforded by the long-term lease arrangement did not act to completely buffer the large pulp companies against market fluctuations. Harvests and exports of the leaseholders declined with (and indeed drove down) overall trends in SE Alaska. Industry analysts suggest these outcomes were likely due "to the marginal position of Alaska wood products firms in the cyclical, integrated and increasingly competitive markets for their products" (Crone 2004).

During the market downturn, harvest levels declined below the ASQ established by the 1979 Forest Plan and later ratified in ANILCA. When market conditions became more favorable in the late 1980s, harvest rates briefly rebounded to exceed the yearly ASQ. The amplitude of the decline (and rebound) during the intervening years (1980-1988) was a measure of the resilience of the SE Alaska industry to external market forces; reflecting the capacity of the system to absorb change with the long-term leases structures in place. At the end of this market cycle in 1990, the long-term lease structures would be weakened by Congress in the Tongass Timber Reform Act of 1990 (TTRA). The long-term leases would be terminated in 1994 and 1997, coinciding with the closure of the associated pulp mills in Sitka and Ketchikan, respectively. These events signaled the transition into the collapse-reorganization stages of Tongass timber management.

4.8 Collapse and reorganization phases [Ω - α] 1990-present

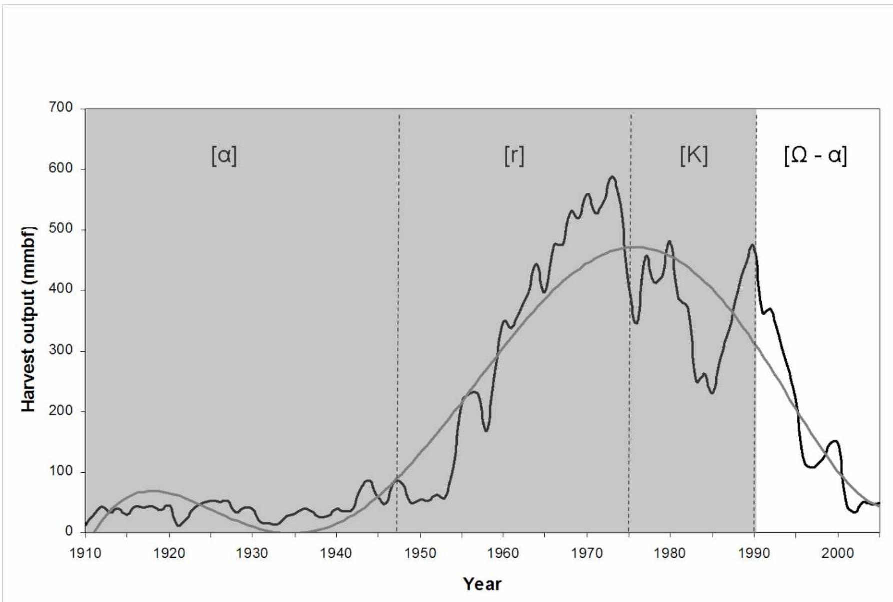


Figure 4.4. Collapse and reorganization stages [Ω - α] of Tongass timber management lasting from 1990 - present day.

"…by the time the contract was breached, APC's long-standing agreement with the [USFS] was a losing contract. The market for its primary product, rayon-grade dissolving pulp, had diminished . . . its current problems were the result of market trends and other adverse circumstances that it determined would not improve in the 20 or so years remaining on the contract"

- 9th Circuit Court ruling in *Alaska Pulp Co. v United States* (2004)

"…on this single day, the Forest Service took a momentous step away from the timber industry-dominated policies of the past and took a giant step toward becoming the 'Conservation Leaders for the 21st Century' - my dream and goal."

- Former US Forest Service Chief Jack Ward Thomas, referring in part to the 1994 cancellation of the APC long-term lease contract (Steen 2004)

The passage of the Tongass Timber Reform Act of 1990 (TTRA) marked the beginning of the collapse [Ω] stage; followed a decade later by the reorganization [α] stage. In a strong rebuke of the legitimacy of the long-term leases and the 'timber-first' mentality of Tongass management since the 1950s, the TTRA mostly dismantled the Tongass policy monopoly. During this period, the closure of the Sitka and Ketchikan pulp mills prompted termination of the long-term leases that dominated Tongass management for four decades.

To conclude the forest succession analogy, collapse is similar to the 'release' phase commonly caused by a stand-replacing event, usually a disturbance such as a fire or disease outbreak that exceeds the resilience of the mature forest. During reorganization, the release of accumulated resources from biomass fosters the regeneration of new vegetation. Likewise, the 'mature' Tongass timber program became rigid, maladaptive and unstable in response to a confluence of events driven by broader shifts in public opinion and global markets. While for decades it absorbed a number of challenges to its authority, the Tongass policy monopoly - and its most significant structural elements, the long-term lease contracts and pulp mills - eventually proved to be vulnerable. The confluence of TTRA reforms, market shifts and non-compliance with environmental regulations (e.g., the KPC Ward Cove mill in Ketchikan was in violation of NEPA water quality standards) drove the system to collapse (Durbin 1999; Nie 2006). This catastrophic disturbance in effect 'released'

Tongass multiple-use philosophy from the timber priority, although the motivation to 'get the cut out' remains a prominent and influential factor to the present day.

Following the mill closures and contract terminations, the USFS faced a new round of lawsuits by long-term lease holders, in addition to increased litigation and appeals by environmental groups seeking to end the commercial production of timber from Tongass lands. The accumulation of several decades of environmental policies and planning statutes drove the USFS into a mode of high costs and 'analysis paralysis' (Williams and Tolle 2001; Steen 2004), in which "the threat of judicial review, injunction, remand, and the like cast a very long shadow on agency decision making" (Nie 2006). Tongass officials have estimated that compliance with federal planning regulations and NEPA (including EIS studies, appeals and litigation) has roughly quadrupled their total per-unit costs for timber sales (USDA 2004). This intractable situation, in conjunction with declining market conditions for SE Alaska timber, drove the timber outputs of the Tongass sharply downward. By 2001, the Tongass timber program had experienced an 88% decline in volume offered and a 92% decline in volume harvested since 1970.

Drafted with the intent of shifting the Tongass away from the dominant timber use, the TTRA repealed the $40 million subsidy and 450 mmbf/yr mandate codified in ANILCA. In its place, Congress instructed the Tongass to "provide for the multiple use and sustained yield of all renewable forest resources", and to "seek to provide" a supply of timber according to market demand. The TTRA modified the long-term leases by eliminating the de facto bidding preference, purchaser road credits, and log-scaling (pricing) advantage given to lease holders. Congress sought to "enhance the balanced use of resources and promote fair competition" in the regional industry and provided rules designed to prevent landscape-scale high-grading, or "[harvest of] a disproportionate amount of old-growth timber." The legislation also ordered the creation of Forest-wide stream buffers to protect local fisheries, with the effect of removing some of the most productive and valuable remaining Tongass stands from harvest consideration (Nie 2006). In sum, these provisions mandated that timber should be in balance with other statutory obligations under the multiple-use philosophy. As interpreted by the Ninth Circuit Court of Appeals, TTRA instructed that Tongass management was to be guided by "not an inflexible harvest level, but a balancing of the market, the law, and other uses, including preservation."

Like most of the significant policies affecting USFS management since the 1960s, the TTRA provided a statutory basis for challenging Tongass decision-making. It ushered in an era in which Tongass decision-making shifted largely to judicial and political venues outside of the agency (Nie 2006). Moreover, because of NEPA and APA, nearly all planning and management decisions were open to a lengthy appeals process, a method often used to obstruct timber sales through delays and costly (additional) environmental assessments. A recent USFS study estimated that from 1997-2003, 88% of NEPA-required EIS decisions were appealed on the Tongass; nearly all appeals were related to timber sales, road permits and other development activities (USFS 2004). Tongass managers claim that timber appraisal, planning and sale activities cost approximately $36 per one thousand board-feet (mbf), while NEPA-related environmental studies, litigation and appeals cost an additional $110 per mbf offered (USFS 2004).

During this tumultuous period, the USFS was in the process of revising its 1979 Tongass Forest Plan. Enacted three years into the Forest planning process, the TTRA required Tongass planners to "go back to the drawing board" (Steen 2004), extending a process that had already taken ten years and cost the agency over $13 million (Nie 2006). The plan that emerged, and the process of its development, was markedly different from its 1979 predecessor. The 1997 Tongass Land Management Plan (TLMP) - incorporating the principles of ecosystem management, species conservation and old-growth reserve networks - reduced the Tongass timber base (total acreage scheduled for timber harvesting) and ASQ by nearly half (to 267 million bf/yr). The 1997 TLMP designated over 36% of the Tongass in a category of land uses named 'Natural Setting', which largely prohibited timber harvesting and extensive road-building in these areas. With the wilderness and National Monument designations of ANILCA, the 1997 TLMP left only 28% of the Tongass land base for timber production (from a high of 96% in 1947).

The election of President Clinton in 1992 led to major shifts at the political levels of the USFS (and its parent agency, the US Dept. of Agriculture), perhaps best symbolized by the appointment of Chief Jack Ward Thomas in 1993. Thomas, a well-respected wildlife biologist, led the reorganization of National Forest policies in Oregon and Washington prompted by political controversy over the Northern spotted owl (*Strix occidentalis*). Clinton removed Chief Dale Robertson, who represented the pro-timber policies of the Reagan and Bush administrations and chose the first non-forester in USFS history to lead the agency. It was a highly symbolic and controversial shift (Steen 2004). Chief Thomas was a central figure in the USFS decision to terminate the Tongass long-term contracts (despite strong political pressure from Alaska's U.S. Senate delegation) and was instrumental in shaping the old-growth reserves created in the 1997 TLMP.

Throughout this period, Senator Ted Stevens remained an influential stalwart of the Tongass policy monopoly. Along with the other members of the Alaska congressional delegation (Sen. Frank Murkowski and Rep. Don Young), Stevens unsuccessfully obstructed the passage of TTRA and opposed the direction taken in the 1997 TLMP. These lawmakers represented the remaining vestiges of the Tongass policy monopoly, and their actions - in concert with the GW Bush administration and its appointees[10] in the USDA and USFS - have facilitated the persistence of early

[10] Mark Rey, the current Undersecretary of Agriculture, was the chief-of-staff for former Senator Frank Murkowski and retains close ties with Tongass managers; Rey is well known for ensuring that

organizing principles in the governance of the Tongass (Nie 2006). Known for his proclivity to funnel federal funds into Alaska, Stevens used his committee position and seniority to exert his influence in the rapidly changing Tongass situation. For example, in exchange for allowing the TLMP process to proceed, Stevens appropriated $110 million of "Tongass Disaster Relief Funds" from the Clinton budget, yielding individual payouts ranging from $30,000 in Sitka to $100,000 in Wrangell (Whitney 1996). Sen. Stevens and the Alaska delegation also used, to varying levels of success, numerous 'riders' to influence Tongass governance, including: a separate annual payment of approximately $30 million in 'relief funds' to the city of Ketchikan, a 1995 provision that would limit the power of the USFS to set new logging limits and conduct environmental research, and a 1998 provision that instructed the Tongass to prepare 253 mmbf for sale the next year and outlined specific legal and fiscal consequences for USFS non-compliance. To the present day, these 'appropriation politics' remain the dominant way the Tongass and its planning process are governed by Congress (Nie 2006).

Most recently, the 1997 TLMP has come under greater scrutiny for its timber component. Due to inflated estimates of market demand by which Tongass managers set the ASQ in the 1997 plan, a Ninth Circuit Court decision found the plan to be in violation of NEPA (Natural Resources Defense Council v USFS 2005). The court found the entirety of TLMP faulty, because of its overestimates of timber demand and its lack of consideration of the cumulative impacts of old-growth logging. Following this ruling, environmental groups claimed that the rejection of TLMP should preempt any further sale planning until a new Plan is approved. The TLMP revisions were completed in December 2006, and subject to a lengthy public comment period, a new plan is expected in August 2007. Further appeals and litigation are certain to follow.

4.9 Discussion

National Forests 'get the cut out' and was instrumental in removing the Tongass from the roadless rule in 2003.

First and foremost, we observe that Tongass management and the SE Alaska timber industry was closely tied to external drivers of change. The origins of a management regime are a reflection of existing social and ecological conditions, institutional philosophy, and the broader social and political objectives in a region (Gunderson et al. 1995). To achieve these goals, management regimes often require a political apparatus capable of defining both ‘problems’ and ‘solutions’ as well as building and maintaining legitimacy (True et al. 1999). This is typically achieved by the formation of a policy monopoly, which operates to confine the venues of debate and decision-making to a small group of actors, allowing managing agencies and private economic interests to cooperate with little external influence (Kingdon 1995; Baumgartner and Jones 1993). The policy monopoly may be viable and resilient for a period of time, but in nearly all cases, proves to be vulnerable to a variety of both predictable and unforeseen factors. In the case of the Tongass, rise and collapse of the management regime paralleled the mobilization and dismantling of its policy monopoly.

Overall the preceding narrative suggests the importance of policy as the primary source of organizing change, stability, and destabilizing change, as we progress through the stages of the adaptive cycle in SE Alaska land management. In the ‘fore loop’ of growth and conservation, the Tongass policy monopoly fostered change by creating the long term leases, and subsequently fostered stability in the management system against external perturbations. Stability was provided in two related ways: first, by maintaining exclusive control over venues of decision-making and planning; and second, by influencing policy-making at various scales as it pertained to the Tongass. For example, the NFMA was passed, in part, to allow resumed timber harvesting under the Tongass-KPC contract. Moreover, as I noted above (and in Chapter 3), the ANILCA debate demonstrated the capacity for the Tongass policy monopoly to stabilize the management regime while one-third of its operating timber base was being removed by wilderness designations. By maintaining the legitimacy of the long-term leases, the policy monopoly 'conserved' its stability in the face of strong destabilizing drivers of change. Over time, however, both sources of policy stability were eroded as the feedbacks of environmental and regulatory reforms accumulated in the management system. The system was vulnerable to these transformative drivers in part because it established structures that became rigid and maladaptive in the face of broader-scale change. Key aspects of the management regime (e.g., clearcutting, pulp mills, and long-term leases) became vulnerable to shifts in public opinion, external market forces, and federal policy.

4.9.1 Cross-scale feedbacks and dynamics

I found that the policy cycle transition into the collapse phase (in 1990) largely drove the collapse-phase dynamics of the management system and the decline of the regional industry (by 1997). This probably occurred because of the tight coupling of the policy and economic cycles. Through the cross-scale linkage of the long-term leases, the policy cycle has driven change in the economic cycle through measures designed either to overcome economic obstacles (in the organization and growth phases), or to repeal these subsidies (in the collapse phase). This coupling of policy and economic cycles is an example of "hypercoherence" (Walker et al. 2004), in which synchrony of multiple cycles generates much stronger feedbacks (than those of individual cycles) on larger-scale dynamics (Holling and Gunderson 2002). In SE Alaska, these feedbacks drove the non-linear dynamics (i.e. state shifts) of the larger-scale federal management system. Hypercoherence was apparent in the strong positive feedbacks that established the Tongass management regime (i.e. transition between organization and growth) and the strong negative feedbacks that later dismantled it (i.e. transition between conservation and collapse). In both cases, external market factors strengthened these feedbacks.

This policy-economic coupling is evident in a comparison of harvest outputs during two different periods of price depression in SE Alaska export markets, in the 1980s while the long-term leases were in place and, in the 1990s after TTRA eliminated much of the long-term lease subsidy. Since its establishment in 1953, the industry was primarily dependent on favorable conditions in Asian pulp markets. Downturns in these overseas markets occurring in the 1980s while the long-term leases were in place (prior to the collapse phase of the policy cycle) resulted predictably in a decline in harvest output; and when market prices rebounded, harvest outputs rebounded to previous levels (Figure 3). In other words, when the policy subsystem was resilient, it afforded resilience to the economic subsystem by assuring investor confidence in the long-term leases and future profit potential (on the next market upswing).

By contrast, when the second market downturn occurred in the early 1990s, in conjunction with the negative feedbacks of TTRA (that dramatically weakened the subsidy structure of the long-term leases), the economic subsystem was less resilient. These feedbacks, coinciding with the collapse phase of the policy cycle, greatly undermined the confidence of industry executives in the reliability of a low-cost timber supply from the Tongass (Borell 2004; Nie 2006). When the lease holders closed the pulp mills, for a combination of policy-related and economic reasons, the contracts were terminated by the Forest Service. Although initially needed to establish the industry, the long-term lease became a rigid and maladaptive structure, because the contracts dictated that the regional pulp mills could only be operated by the lease holders. When the leases were terminated, the region immediately lost nearly all of its capacity to process the low-grade materials that comprise much of the regional timber base. Therefore, the rigidity of the arrangement between the pulp mills and the long-term contracts led to structural changes, rapid declines in productivity, and loss of flexibility in the regional industry.

Despite improving markets in recent years, industry production has remained near historical lows, similar to outputs during the pre-pulp years. The fact that production outputs have not rebounded with improving markets suggests that the regional industry has lost some degree of the flexibility that was apparent during the market downturns of the 1980s. One explanation for this outcome is the decline of SE Alaska mill infrastructure; in terms of technology and efficiency, the majority of regional mills have remained mostly unimproved since the 1980s (or earlier). Several industry analysts suggest mill technological improvements in SE Alaska are needed to compete in global timber markets (Morse 1998; Crone 2004). Yet given the high degree of uncertainty whether timber sales will survive NEPA appeals and extensive litigation (Malmsheimer et al. 2004), any substantial increase in private investment in modernizing local mills is unlikely in the near term (Nie 2006). In this way, the policy cycle has transformed the larger management system by requiring the closure of the regional pulp mills (which are needed to locally process much of the region's timber resource), by greatly complicating the planning process with regulations and appeals, and by reducing investor confidence in a reliable and affordable timber supply (Alaska Forestry Association 2004).

4.9.2 The 'pathology' of natural resource management

The history Tongass management suggests an example of the "pathology of resource management" as described by Holling et al. (2002):

> "New policies and development usually succeed initially, but they lead to agencies that gradually become rigid and myopic, economic sectors that become slavishly dependent…and a public that loses trust in governance."

This pattern and its outcomes in SE Alaska are clearly apparent in the case study of the adaptive cycle of Tongass forest management. An initial period of rapid growth was followed by a conservation stage in which the typical outcomes of the management pathology became apparent. Tongass managers were bound to the rigid requirements of the long-term contracts regardless of change in the political and economic landscape of SE Alaska. For decades, Tongass resource management was principally focused on planning timber sales and sustaining the prosperity of the regional industry. Moreover, it was apparently a short-term focus, because there were no binding stipulations in the long-term contracts requiring private investment in managing second-growth stands for future timber production or other uses (Durbin 1999; Steen 2004). The Forest Service subsumed this responsibility, as it did for the maintenance of logging roads and stream culverts that were built with mostly public funds. The SE Alaska timber economy was 'slavishly dependent' on both the long-term leases providing low-cost Tongass timber and the favorability of global market conditions. This has been a typical outcome in subsidized timber programs on US National Forests (Repetto 1988). Lastly, and perhaps most significantly, the loss of trust in governance is quite obvious, for both environmental advocates and local stakeholders. After collapse of the timber industry, the Tongass finds itself wedged between these groups, and the atmosphere of deep mistrust is pervasive.

Federal land management in SE Alaska is now in a critical period that will largely dictate its future, just as in the earlier organizational phase of the early 20th century. Clearly the Tongass exists in a very different set of conditions than when the industrial forestry idea emerged and was legitimized as the primary thrust of resource management. At present, a rapidly growing regional tourism industry, and an increased awareness of the importance of old-growth forest habitat for fish and wildlife populations (that support subsistence and commercial economies) makes the prospect of resuming industrial-scale forestry in the region unlikely. Thus, the retention of this approach as an organizing principle in resource management will almost certainly result in a continuation of the existing "deadlock"; because the current atmosphere of litigation, politicization and mistrust exists largely as a legacy of the long-term pulp contracts in the region (Durbin 1999; Steen 2004; Nie 2006). The realignment of Tongass management into a more sustainable regime ultimately depends on the reconciliation of the conflicts among local and national stakeholders, their advocates, and the agency that manages their interests for the common benefit. These topics are addressed in depth in the second half of this case study (Chapter 5).

Chapter 5

Factors influencing the reorganization of federal land management

5.1 Summary

In a continuation of the case study of Tongass management during the 20th century, this chapter focuses on the years since collapse of the timber industry and its supporting management regime. My overall objective was to characterize conditions and controls that have shaped the behavior of Tongass management during the current reorganization phase. I hypothesized that Tongass management presently exists in a different set of economic and political conditions than the conditions both prior to, and during the boom years of SE Alaska timber. This hypothesis is evaluated based on trends in regional conditions during the period encompassing industry collapse and the recent years of "deadlock" (1990-2005). Current conditions are described using several indicators of market demand, industry structure, and bidding behavior. I then conducted a comparative analysis to generate quantitative and qualitative insights on whether Tongass management has adjusted in accordance with local and global changes affecting the timber industry. This approach identified examples of inertia in management, such as the continued offering of large volumes of pulp-grade timber, despite the region's loss of its entire pulp processing capacity. I also identified examples of adaptation in management, such as the growth in microsale offerings which better meet local timber demand. The origins and/or sources of inertia-driven and adaptively-driven behavior in Tongass management are then described. Overall, I found that retention of clearcutting practices, the broader industrial-scale sustained-yield philosophy, and the highly contentious and litigious atmosphere surrounding Tongass decision-making were critical sources of inertia. By contrast, Tongass managers have also shown the capacity to adapt, through flexibility in harvest methods, a willingness to meet local demand instead of politically-determined production targets, and a growing degree of *a priori* cooperation with environmental

groups. In reorganizing Tongass management for the future, I argue that the tension between inertia and adaptation will largely determine forest management practices and policies, and their outcomes for the social-ecological system of SE Alaska.

5.2 Introduction

The history of the Tongass timber program, as viewed through the lens of the adaptive cycle, provides many insights into its current state and potential futures (Chapter 4). In particular, the perspective illuminates how both 'remnant' and 'new' factors have shaped recent reorganization and suggests how these factors may affect the system's trajectory into a new 'loop' of the adaptive cycle. Many of the same drivers of change and sources of stability and vulnerability that dictated past system behavior remain in the current Tongass system. New elements and external conditions prevail as well. At present, these forces interact to maintain the highly litigious and polarized "deadlock" that has become a global icon of the environment versus development debate (Durbin 1999; Nie 2006).

In the debate over the Tongass, environmentalists claim that the continued emphasis of timber production by the Forest Service is both a myopic and wasteful course of action. Environmental groups claim that much of the 'biological heart' of the Tongass has already been logged, and no further degradation should be permitted. They also cite the high cost and net loss operation of the Tongass timber program as a waste of taxpayer dollars, because most offers are not sold or harvested. More broadly, they argue that federal support for logging represents an unfair subsidy to the timber industry. A recent report from a local environmental group estimated that the $40 million Tongass timber budget supported fewer than 600 jobs in the region; representing a federal "subsidy" of nearly $170,000 per job (SEACC 2004). Local and national advocacy groups insist that the only way to affect this situation is through the multiple venues of litigation and appeals that were established over several decades of national environmental reforms.

In response, timber industry advocates and Tongass managers claim that environmental litigation is the principal reason why timber planning and harvesting costs are so high; and thus why the timber program appears to be very wasteful of taxpayer dollars. They cite the increased difficulty in "bullet-proofing" management plans to withstand the appeals and litigation process that environmental groups use as "stalling tactics" and "economic vandalism" (Soderberg and DuRette 1998; Alaska Forestry Association 2004). They also cite the fact that nearly all Tongass NEPA assessments are appealed, thus requiring further study and often prolonged delays, thus reducing bidder confidence that the timber can actually be harvested in a reasonable period of time. Given the volatility and interdependence of global timber markets for SE Alaska exports, it is important for local operators to be able to respond rapidly to market opportunities. Industry advocates claim that appeals and litigation greatly constrain this much needed flexibility. Moreover, Tongass managers claim that less than 5% of the Forest has been logged, less than one-third of the Forest is managed for timber production, and that vast wilderness and 'natural setting' areas afford strong environmental protections for many biologically rich places.

Both arguments have valid points, but more importantly, they reflect the underlying difficulty of the current deadlock. Instead of laying blame in one direction or the other, it is more useful to consider those factors that constrain the reorganization of Tongass management into a workable and sustainable compromise - this is the goal of this chapter. Chapter 4 suggests that the current Tongass situation has many things in common with a system post-collapse: new 'environmental' conditions and controls, as well as remnant conditions and controls of the past system. The current deadlock has emerged from the interactions among these factors, which will, in turn, shape the future configuration of the management system in SE Alaska. Because the timber remains the principal controversy, its resolution requires an understanding of the factors that resist or foster adaptive change. In this way, we may begin to understand how to progress out of the current “quagmire” on the Tongass (Nie 2006) and towards a sustainable management regime in SE Alaska.

5.3 Objectives

The purpose of this chapter was to characterize conditions and controls that shape the behavior of the Tongass management system during the current reorganization phase. To this end, the first objective was to describe the extant regional conditions, or ‘state space’ in which the Tongass timber program presently exists. This state space is defined by the current configurations of the policy subsystem (e.g. Tongass planning and budgetary governance) and the economic subsystem (e.g. industry structure and capacity, market demand/value). I hypothesized that Tongass management in the current reorganization phase [α_2] exists in a different state space than the initial organization phase [α_1] and the subsequent conservation phase [K]. This hypothesis is evaluated based on trends in regional conditions during the period encompassing industry collapse and the recent years of “deadlock” and reorganization of Tongass management (1990-2005).

If a state-shift has occurred in regional conditions, as the previous chapter suggests, then has an associated state-shift occurred in the objectives and practices of Tongass timber management? In other words, to what degree has Tongass timber planning adjusted to match the current conditions in SE Alaska? To answer these questions, I conducted a comparative analysis based on a framework that defined current conditions as ‘explanatory’ variables and Tongass timber planning as the ‘response’ variable. This framework allowed the statistical and/or qualitative comparison of related trends over the same time period; e.g., changes in regional pulp processing capacity, and trends in the amount of pulp-grade timber offered by Tongass managers. This general approach was used to compare a range of explanatory and response variables, yielding some insights on whether a state shift has in fact occurred within Tongass timber planning and practices.

The second goal of the chapter is to understand why such a state shift either has or has not occurred in Tongass management. To this end, I identified examples of 'mismatches' in trends in order to characterize the system components/controls which contribute to inflexibility (or inertia) in Tongass management. Inertia provides stability in the current state or, if it fosters change, drives the system to return to its past configuration (e.g., industrial-scale forestry in the Tongass). I also looked for examples of 'matches' in trends in order to characterize the system component/ controls which contribute to adaptive capacity (or adaptation). Adaptation indicates the transformability of the system, driving towards a new and potentially more sustainable configuration. In the reorganization phase, the forces of inertia and adaptation interact to determine the future state of the management system: whether it remains in the current quagmire indefinitely, remobilizes industrial forestry, prohibits future timber harvesting, or finds some new balance between timber and other forest uses. I address these scenarios in a discussion of the critical obstacles to Tongass reorganization, and the challenges and opportunities involved in reaching sustainable outcomes for SE Alaska.

5.4 Methods

5.4.1 Data sources

I relied primarily on USFS sources of data to describe: (1) Tongass timber program outputs (offers, sales and harvest by sale type, species and product type), and (2) relevant economic factors (stumpage rates, mill capacity and utilization, sale bids). Most data were acquired from the USFS Alaska Region through a FOIA request; the rest was gathered from published USFS technical reports, agency press releases, and journal articles. These data did not include 'releases' of timber under the long-term contracts (only pertinent until 1997) for three reasons: the long-term contract outputs are not the focus of this study, the data have limited availability due to the confidentiality of contract operations, and the long-term leases were managed separately from the rest of the Tongass timber program (Morse 1998; Steen 2004; Nie 2006). Thus the analysis of program outputs focused on the smaller, non-lease offers that became the entirety of Tongass sales and harvests after the cancellation of the last long-term lease in 1997.[11]

5.4.2 Describing regional conditions

Trends in regional conditions and were described based on economic factors (e.g., mill processing capacity and utilization, industry structure, timber prices, bid prices) and political-institutional factors (e.g., appeals and litigation). Mill capacity data was derived from two studies (Morse 1998; Brackley et al. 2006), including the three sawmills affiliated with the KPC and APC pulp mills, but not the pulp mills themselves. The FOIA data on sale status included the small proportion of sales cancelled due to litigation, but these data represent only a fraction of legal opposition because the appeals process has been used much more frequently (Nie 2006). Sale-specific appeal records were not available in a format suitable for statistical analysis. The Tongass also does not maintain summary records of NEPA-related and litigation expenditures on an annual basis. Thus the best estimate of appeal/litigation intensity was derived from summaries of NEPA actions in the Tongass from 1970-2004 (Malmsheimer et al. 2004; Nie 2006).

5.4.3 Measures of Tongass planning and governance

For the analysis of timber program outputs, I focused on the period of 1990-2005, coinciding with the collapse-reorganization stages [Ω-α] described in the preceding chapter (also see Figure 5.1 this chapter). I examined trends in the types of sales offered, species and rate (advertised price) of stumpage, estimated logging-related costs, and fate of the offer (sold, unsold, under litigation). For the broader governance of the Tongass, I drew largely from the previous chapter to describe factors that influence the agency's management priorities in SE Alaska, including

[11] The timber volume that remains 'under contract' with KPC is not included in the analysis, because its status has not changed since the cancellation of the long-term lease in 1997.

budget riders, appropriations, and other forms of influence from national lawmakers. Insights on these factors were largely qualitative.

5.4.4 Analytical approach

After constructing the datasets and describing the patterns of change in regional conditions and Tongass timber program outputs, I compared these patterns using related pairs of variables. Since most of the information used in this study was not suitable for statistical analysis, a great deal of the resulting analysis is qualitative. Wherever possible, I have incorporated empirical and statistical measures (e.g., pairwise correlations) to support my qualitative insights. As a result, the analysis herein is not systematic in a traditional sense, but represents an attempt to synthesize the best available information.

The primary goal was to determine the reasons whether or not Tongass planning has reorganized in accordance with the shifts in regional conditions that have occurred since 1990. Many of these regional shifts occurred abruptly, such as the closure of the regional pulp mills (and associated 'feeder' mills) in 1994 and 1997. These events immediately changed the structure of the regional industry by eliminating its capacity to fully process pulp logs. By observing the trend of pulp-grade timber offered by Tongass managers during this period, I interpreted whether Tongass timber planning has adjusted to this change. I framed these observations in terms of inertia and adaptation, as defined below.

Inertia was defined as any trend (or lack thereof) that suggested the influence of organizing principles and elements of the past system [α_1], i.e., institutional behavior reflecting the formerly dominant approach during the long-term lease years. Cases of inertia were also apparent when the available data suggested a mismatch between timber planning and current conditions. For example, the closure of the regional pulp mills eliminated the local capacity to fully process low-grade materials (that must be exported on very slim or nonexistent margins). The continued offering of large volumes of low value, pulp-grade hemlock without any regional pulp mills for these materials would be an example of inertia.

Adaptation was defined as any trend that suggests a 'new direction' emergent during the current reorganization stage. This includes any instances where Tongass planning has adjusted to recent shifts to better 'match' current conditions. For example, if Tongass managers reduced their offering of pulp-grade timber in proportion to the diminished local capacity to process these materials, it would be an example of adaptation.

5.5 Results

5.5.1 Current regional conditions

Trends in SE Alaska mill capacity fluctuated throughout 1981-2004 (Figure 5.2), consistent with the frequent mill closures and reopenings during this period (Morse 1998; Brackley et al. 2004). Permanent mill closures (the APC sawmill in Wrangell and the KPC mills in Ketchikan and Annette Island) drove the overall decline of regional mill capacity during this time. Mill utilization, as a percentage of total capacity, exhibited an inverse relationship with mill capacity until it began a steady decline in 1992 to reach less than 25% of capacity by 2004 (Figure 5.2). Most of this decline occurred rapidly between 1992 and 1995. In subsequent years, utilization as a percent of capacity has varied in parallel with mill capacity trends. Moreover, the growing importance of small craft mills during this time suggests structural changes in the SE Alaska industry, in addition to the changes driven by closure of the pulp mills in Sitka and Ketchikan. From 1981-1998, approximately 10% of regional capacity was provided by a group of small sawmills (i.e., any mill with less than 15 mmbf/yr capacity). By 2004 this proportion had increased to nearly one-third. In 2003 and 2004, only about 10% of capacity was utilized by both small mills (9.1%)

and larger mills (12.2%). Low capacity utilization may be the result of several factors that are addressed further in the discussion.

During the same period, the timber-sale bidding environment appears to have shifted into a different condition (or 'state') characterized by much lower advertised stumpage rates and winning bid values (Figure 5.3). The number of bids per sale from 1990 to 2005 exhibited high interannual variability but no significant linear trend. Meanwhile, both the mean advertised price of stumpage and the mean winning bid amount declined to reach their low in 1998, and both variables have remained relatively stable near this minimum to the present day. The Tongass advertised rate for all timber species has declined considerably since 1998 (Figure 5.4). Relationships among bidding-related variables shifted during this time as well. Based on a comparison of interannual variation between total bids and advertised stumpage prices (Figure 5.3), the data suggest that their relationship shifted from an inverse (Pearson r = -0.32 from 1990-1997) to a positive correlation (Pearson r = 0.63 from 1998-2005). This suggests after 1998 there were more bids for the higher-value sales, while prior to 1998 the higher priced sales had fewer bids.

In recent years, appeals and litigation have become the primary method of stakeholder participation in Tongass decision-making. From 1997-2003, the USFS reports that 88% of all Tongass Environmental Impact Statements (EISs) and 26% of NEPA Environmental Assessments (EAs) were administratively appealed. Roughly half (47%) of Tongass EIS studies since 1991 have been challenged in federal courts; as of May 2005 there were fourteen sales under litigation on the Tongass totaling 238 million board-feet (Nie 2006). Studies estimate an overall 45% success rate of litigants against the USFS under NEPA from 1970-2004 (Malmsheimer et al. 2004), while the proportion of sales challenged in court has increased dramatically since 1990 (Nie 2006). Nearly all appeals and litigation on the Tongass have pertained to timber sales, roads, and related activities.

Tongass managers have estimated that costs associated with NEPA compliance, EIS appeals, and litigation constitute over 75% of their expenditures for timber sale planning (USDA 2004). They also frequently cite the increased effort and expertise needed to 'bullet-proof' their timber-related plans to withstand appeals and litigation (Williams and Tolle 2001; Nie 2006). The costs and delays associated with the NEPA appeals process resulted in many offers never being sold, although the precise number is unknown because of data limitations. In a five-year review of the 1997 Forest Plan, Tongass officials claimed that appeals, litigation, and court orders have "stalled the Tongass in achieving a reliable or predictable Federal timber supply" (USFS 2005). Since 1997, the volume of offers, sales, and harvests has never met the allowable sale quantity (and planned harvest level) of 267 mmbf/year established in the 1997 Forest Plan (Table 5.1).

Other emergent changes have occurred that present specific issues, such as yellow-cedar decline. Likely the result of recent climatic warming in SE Alaska (Chapter 2), the widespread dieback of cedar has emerged as both a challenge and opportunity. It is a challenge for researchers to understand the mechanisms of decline, which are important for understanding the viability of yellow-cedar, both as a species and a highly valuable local resource. Yet salvageable cedar is widely available in declining stands, and the Forest Service has funded efforts to demonstrate and market its unique and valuable properties, and local mills have a high demand for the wood. Moreover, salvage harvesting is a simpler proposition in the complex planning/appeals process required by NEPA, because salvage can be framed as a forest health measure, instead of just a development activity.

5.5.2 Inertia

Given the shifts in regional conditions described in the previous section, I found several examples of inertia in the planning of timber sales during the reorganization period. First, the species and product composition of timber sales did not shift to account for changes in local processing capacity. Old-growth hemlock continues to dominate the offered stumpage while the offer of higher value species such as Alaska yellow cedar and Western red cedar - that can be fully processed by local mills - has remained relatively low (Figure 5.5). With the exception of 2003, when Sitka spruce (mostly higher-grade sawmill material) exceeded the volume of hemlock offered, the Tongass has continued to offer more of the low-grade, pulp-quality timber. Pulp-grade materials can be processed locally (into four-sided cants), but must be exported for the majority of value-added processing steps; most pulp cants are currently sent to 'Lower 48' mills.

Second, from 1990-2005 the ratio of pulp[12] to saw material offered on the Tongass exhibited no significant trend, despite the closure of the regional pulp mills (Figure 5.6). During this period, the pulp-to-saw stumpage ratio fluctuated around a stable mean, reaching its maximum (0.25) in 2004, while the ratio of pulp cants to sawtimber produced by SE Alaska mills (0.09) has remained low. This discrepancy may occur partly because at recent market prices, pulp-grade cants exported from SE Alaska have a very narrow profit margin. Federal law prohibits export of unprocessed pulp logs from the Tongass.

The composition of the Tongass timber base is a primary reason why pulp-grade materials continue to be a major component of Tongass timber sales, even after closure of the regional pulp mills. As it was when the first Tongass managers proposed timber management for industrial pulp production, much of the old-growth in SE Alaska is composed of Western hemlock and Sitka spruce of highly variable

[12] The USFS data has three categories for product type: saw, pulp and miscellaneous. I calculated total pulp volume by summing the pulp and miscellaneous categories, because from 1988-1996, all pulp-grade materials offered (outside of the long-term contract releases) were classified as 'miscellaneous.' Although all timber harvested on the Tongass must be locally processed to some degree (with the exception of Alaska yellow cedar), nearly all pulp and miscellaneous materials must be exported for value-added processing.

grade. As a result, nearly all sale units contain a significant proportion of low-value materials. The continued preference for clearcutting contributes greatly to this situation. While it is often most efficient practice from both an economic and management standpoint, clearcut logging requires the harvest of all trees within the sale unit. As a result, it is inherently difficult to design a clearcut sale unit of sufficient size that contains mostly high-grade timber. In many cases, selection harvesting is more suited to this goal, especially considering the structural changes to the regional industry, the composition of old-growth stands, and the high value of certain species (e.g. western red cedar, Alaska yellow-cedar). However, selection harvesting as a dominant forestry practice is frowned upon by Tongass managers as a variation on the high-grading practices of the past (A. Brackley, *personal communication*). To this day, clearcutting has dominated timber harvest on the Tongass, with the exception of a three-year period (2000-02) when selection harvesting became a comparably significant method (by area harvested; Figure 5.7).

The types of sales offered provide another example of inertia-driven behavior. For example, salvage sales to remove dead trees may be more suited to current conditions in SE Alaska, for several reasons: they are generally simpler and less expensive to plan, may involve lower logistical costs (when they use the existing road system), can simultaneously serve forest health and timber production goals, are exempt from certain NEPA obligations, and are thus less frequently appealed and/or subjected to extensive litigation. Despite these potential advantages, salvage sales have remained a low proportion of total sales offered throughout the reorganization period (Figure 5.8). The widespread decline of highly valuable Alaska yellow-cedar across nearly 500,000 acres of SE Alaska represents a largely untapped opportunity for salvage (Hennon et al. 2005).

Lastly, at the broader scale of Tongass governance, a major source of inertia arises from the influence of remnants of the policy monopoly. While the Tongass policy monopoly no longer dominates the venues of debate and decision-making, and its overall ability to affect the 'on the ground' Tongass situation has diminished greatly, it remains influential in a very important venue - in the appropriations and budgetary responsibilities of Congress (Farnham 1995). In 1995, all three members of the Alaska delegation assumed powerful roles: (former) Sen. Frank Murkowski became Chair of the Senate Energy Committee, Sen. Stevens became Chair of the Senate Appropriations Committee, and Rep. Don Young became Chair of the House Resources Committee. In these powerful positions, Alaska policymakers have exerted their influence through the frequent use of Tongass-specific (and even project-specific) riders on large federal omnibus bills, a series of over twenty hearings on the Tongass from 1994-98, and an unsuccessful attempt to transfer the Tongass to the State of Alaska. Budget riders included a 1995 provision limiting the power of the USFS to set new logging limits and conduct new environmental studies, and a 1998 measure instructing the USFS-Tongass to sell enough timber to support 2500 local jobs, prescribing a precise harvest amount and specific fiscal and legal penalties for Tongass non-compliance. These 'appropriation politics' are the primary way in which the former policy monopoly continues to govern the Tongass, although in a more adversarial fashion than during the boom years (Farnham 1995; Nie 2006).

5.5.3 Adaptation

In recent years, Tongass managers have exhibited adaptive behavior as well, with the goal of better aligning their timber management approach with current conditions in SE Alaska. The 'microsale' program represents a shift in timber sale planning to better suit the recent structural changes in the regional industry. The program offers very small quantities of high-grade timber, mostly Sitka spruce (55%) and Western red cedar (26%) for processing by local craft mills (Table 5.2). All of the microsales have been offered in two ranger districts on Prince of Wales Island, where an extensive road network (largely provided by historical timber operations) and several local mills minimize logistical costs. Microsales can be harvested by the selection method and the timber removed by helicopter yarding; these practices have minimal environmental impacts compared to clearcut harvesting. For these reasons microsales are exempt from certain planning regulations and NEPA requirements, thus reducing the effort and expense of Tongass planners. Most importantly, the cooperation between local environmental groups and the Forest Service in developing the microsale program has allowed the Tongass to proceed with relatively few legal or administrative obstacles. By 2004, during its fifth year of operation, the microsale program grew to comprise one-third of all sales offered (Figure 5.8). The very low level of capacity utilization, especially among small craft mills (9.1%) suggests that there is room for additional growth.

Despite the early success, the microsale program has averaged only 0.23% of the total Tongass volume offered since it began in 2000. Thus microsales contribute very little to the overall mandate by Congress (and TLMP) for Tongass managers to offer a volume of timber similar to the 267 mmbf ASQ set in the 1997 Forest Plan. While this ASQ was not an accurate reflection of market demand for Tongass timber (*Nat. Res. Def. Council v USFS 2005*), the pressure to reach these harvest levels has remained strong from industry advocates, state officials, federal legislators and appointees at the highest levels of the US Department of Agriculture (Durbin 1999; Nie 2006). Continued effort on microsales may be a sign of a willingness to adapt to meet local demand, instead of focusing solely on meeting harvest targets that are largely determined by policy makers, political appointees, and high-level bureaucrats, instead of professional foresters responding to local demand (Repetto 1998).

Two further examples of adaptation emerged in 2006: 1) a redoubled emphasis on active management of second-growth stands (which invests USFS resources into future, not contemporary, commercial harvest yields); and 2) the signing of a 'Memorandum of Understanding' between the Tongass/USFS Alaska Region and The Nature Conservancy (TNC), a well-respected, privately-funded conservation organization. First, the investment in second-growth management is critical; thinning of young second-growth forest accelerates growth rates, improves timber quality and hastens the development of forest structure to an old-growth condition. Prior to the new initiative, the USFS funded thinning operations at an almost certainly insufficient level to pre-commercially manage second-growth forests. While detailed budget data on the yearly expenditures on thinning was unavailable, one agency official estimates the current funding for thinning affords no greater than 4000 acres of second-growth forest each year (S. Snelson, *pers. comm*). There are nearly 500,000 acres of second-growth forests on the Tongass. A renewed emphasis on second-growth management suggests recognition by Tongass managers that the future of the SE Alaska timber economy may largely depend on second-growth.

Second, the 2006 memorandum symbolized the first significant public partnership in Tongass history between USFS administration and an environmentally-oriented interest group. The USFS-Tongass and TNC have held a series of meetings and public seminars discussing a 'restoration economy' based on managing second-growth forests for joint ecological and economic goals. One of the projects discussed was the creation of jointly funded (TNC and USFS), community-based programs for commercial thinning of second-growth stands to provide improved wildlife habitat, product flows to local mills, and subsistence/recreational opportunities. Although this type of project is still mostly in its conceptual stages, Tongass officials have become noticeably more receptive to a vision of multiple-use in which timber management can work in concert with other goals.

5.6 Discussion

I found examples of inertia in both planning and overall governance of the Tongass. The 'regular' sales that comprise the vast majority of timber offered still look much like the sales offered during the industrial 'pulp' years. Despite the loss of regional pulp mills and the legislative requirement to locally process nearly all Tongass timber, the ratio of pulp to saw grade timber offered has not changed significantly. This is likely because the majority of Tongass timberlands are composed of pulp-grade hemlock, and the practice of clearcutting requires the harvesting of considerable amounts of pulp-grade hemlock. The Forest Service can do little to change this ecological reality in the old-growth forests of SE Alaska. However, forest managers remain bound by its constraints because they have not exercised their discretional authority to shift towards other harvest methods.

The dominance of clearcut harvesting in Tongass timber management seems rational and appropriate under certain conditions. It suited the initial conditions in SE Alaska and the even-aged management objectives of the Tongass. The clearcutting approach has its origins in the sustained-yield policy of managing timber resources in US National Forests. This institutional philosophy was codified in the Sustained Yield Management Act of 1944, and following several judicial decisions in 1975 enjoining the practice in National Forests, the practice was reaffirmed by the National Forest Management Act of 1976 (Chapter 4). Economically, clearcutting was legitimized by the more diversified SE Alaska timber industry of the past, which was capable of processing a wide range of grades. Moreover, the mandated 450 mmbf/year Tongass harvest level set by ANILCA left timber planners with little choice; the only feasible manner to reach this target harvest (and the subsequent ASQ level set in the 1997 Forest Plan) in SE Alaska was through clearcutting. However, the practice has become a highly politicized issue with the majority of national public opinion strongly opposed to its use, especially on public lands (Bliss 2000). Most importantly, the impacts of clearcutting on fisheries, wildlife and recreational opportunities are often the basis upon which environmental groups challenge sales under NEPA EIS (Malmsheimer et al. 2004). For these reasons, the emphasis on clearcutting has become a source of inertia in current Tongass timber planning.

This inertia has probably constrained the capacity of Tongass managers to take advantage of emergent opportunities, such as yellow-cedar decline. There are over 300,000 acres of declining and standing dead cedar across SE Alaska, which remain highly valuable because of the unique decay-resistant qualities of yellow-cedar heartwood (Hennon et al. 2005). Salvage sales are more easily justifiable from a forest health perspective and can bypass many of the NEPA requirements for timber harvesting projects. Judging by the observation that nearly all cedar salvage offers are competitively bid upon and sold, there is a high local demand for the wood. The Forest Service has invested millions of dollars into research and marketing of the unique properties of yellow-cedar lumber, in an effort to increase its already high premiums. Yellow-cedar is currently almost three times more valuable per board-foot than the next most valuable species in SE Alaska (Sitka spruce).

My findings suggest that Tongass managers have not taken advantage of the yellow-cedar opportunity by significantly increasing the availability of cedar in salvage sales. The principal reason is because the removal of dead cedar would involve the high-grading of stands that Tongass managers plan to clearcut in the future; and to a lesser degree, because it involves logging in areas where development is not allowed, such as Wilderness Areas. With good reason, forest managers are highly reluctant to liquidate a valuable resource that does not appear to be renewable in the near term, because most declining cedar stands are either regenerating very slowly, or not at all (Hennon et al. 1990). Yet it appears there is some room for expansion of cedar salvage efforts, while maintaining large unmodified areas of dying cedar forests for research and management efforts, such as restoration. Tongass managers simply do not want to reduce the value of future clearcut harvest units by removing the high-grade cedar (A. Brackley, *personal communication*).

Yet the Tongass has been willing to high-grade (to some degree) in recent years, judging by the growth of the microsale program, which tends to operate by selection harvesting (or very small clearcut units). In response to structural shifts in the regional industry and the growing importance of small craft mills, the Tongass microsale program has been initially successful. A minor yet growing component of timber planning, the microsale program suggests a partial return to initial organizing [α_1] conditions in the reorganization stage [α_2]. Every microsale has been competitively bid upon, sold, and harvested. By comparison, since 1990 roughly half of the traditional large clearcut sales have been bid upon and sold. Microsales are designed to meet local demand, much like the pre-industrial approach of Tongass managers in the initial organization [α_1] stage. Microsales are significant not only because they appear to serve local timber demand more flexibly, but also because they often involve alternative methods of harvesting (e.g., selection logging by helicopter) that have lesser environmental impacts. For this reason, and because the program came about through cooperation between the USFS and local environmental groups, microsales are rarely targeted by legal action. As beneficial as the program appears to be, it comprises a miniscule fraction of the total volume offered and sold on the Tongass, thus it does little to help forest planners meet the harvest targets designated in the 1997 Forest Plan.

In the broader institutional sense, the emergence of the microsale program may reflect a shift in philosophy in Tongass timber management: a transition from unilaterally working to meet a politically-determined harvest level, towards satisfying local demand in cooperation with various stakeholder groups. The 'new' politics of Tongass reorganization has timber managers wedged squarely between two powerful coalitions: the timber industry and environmentalists. The microsale program, while not a complete solution to the quandary imposed by environmental litigation and appeals, may suggest that the political position within the Tongass administration has shifted (if only slightly) towards a greater degree of *a priori* cooperation with environmental groups. In other words, the Tongass may be beginning to adapt to its new political landscape.

If this adaptation is occurring, it is constrained by powerful remnants of the Tongass policy monopoly that continue to influence management through budgets, riders, hearings, and agency pressure. Alaska's congressional delegation has actively sought to re-establish a booming timber industry in SE Alaska. By dictating the relative funding levels of different Tongass programs (e.g., timber, wildlife, subsistence, and recreation) through the budget and appropriations process, this effort has become a source of inertia in overall Tongass governance. The new economy of SE Alaska is strongly dependent on the goods and services of unmodified ecosystems, which support consumptive uses like hunting and fishing, as well as the non-consumptive uses and amenity values associated with pristine scenery and remote recreation (Colt 2006). Yet the timber portion of the Tongass budget remains greater than all other programs combined (Nie 2006). Alaskan policymakers view their actions partly as a response to the "broken promises" of ANILCA (Stevens 2000) and as the only stalwart against the "economic vandalism" practiced by environmental groups in SE Alaska (Soderberg and DuRette 1988). Environmentalists respond with the argument that continued funding for timber is a myopic approach to multiple-use and an unfair subsidy to the timber industry. This debate has fostered the highly politicized climate of mistrust among Congress, environmentalists, private industry, local stakeholders, and the USFS in SE Alaska.

This litigious and contentious atmosphere is a source of inertia, as it impedes the cooperation and 'friendly' participation of various stakeholders in the Tongass planning process, where any adaptive new directions would either originate or have to be implemented. With the exception of some recent *a priori* cooperative efforts, most of the participation of advocates (of either side of the debate) occurs outside of the planning process, in the courts or in Congress. As long as mistrust and controversy persist, they act as inertia by maintaining the system within a certain stability domain; e.g. the "quagmire" or "deadlock" that typifies the current situation. While the broader 'environment versus development' debate will continue to influence resource management decision-making almost everywhere, the Tongass has become a globally-recognized icon of this conflict, and thus is now a battleground for some of its most radical advocacy coalitions (Cahn 1988; Wilkinson 1997; Borell 2004; Nelson 2004; USDA 2005; Nie 2006). As a result, Tongass managers are constantly involved in litigation and thus appear to be seriously constrained in developing more adaptive and forward-looking management policies.

However, the renewed emphasis on second-growth management suggests that Tongass managers have recognized the importance of this resource to the future timber industry and its dependent communities. Moreover, it implies that Tongass managers are realizing that a remobilization of industrial forestry will have to wait until second-growth stands mature, because opposition to old-growth logging is too strong. In a key development that both addresses second-growth forests and may serve to ease tensions, an unprecedented degree of cooperation has been initiated between the USFS and The Nature Conservancy of Alaska. The broad objective is to manage second-growth for a range of social and ecological benefits, in part through greater stakeholder participation and adaptive management techniques. Second-growth thinning is essential for achieving the desired 80-150 year rotations of sustained yield forestry in most forests of SE Alaska (Taylor 1935; Soderberg and Durette 1988). Its implementation, although on a smaller timber base than originally envisioned by Tongass managers, represents an investment in a future production forestry regime. Thinning may also simultaneously serve other purposes that have been considered mutually exclusive land uses in the past; e.g. improvement of species habitat and local economic growth (through employment and local investment in thinning projects). Thus the opportunities afforded by the 'restoration economy' demonstrate that forest management in SE Alaska is not a zero-sum game; in other words, actions that benefit future timber uses can also benefit non-timber uses.

5.7 Conclusions

Looking forward, we can conceive of four generalized outcomes of the reorganization phase of Tongass management: (1) persistence of the contentious "quagmire" situation, (2) a remobilization of industrial-scale forestry, (3) a permanent prohibition of timber harvesting, (4) a cooperatively determined balance among timber and other forest uses. In theory, these scenarios can be characterized in terms of the dominant forces (inertia or adaptation) shaping the future configuration, and the system dynamics (stable or transformed) in that state. This framework is described in Figure 5.9. In the first 'inertia-stable' scenario, inertia resulting from the current controversy and its constraints on adaptive capacity will stabilize the management system in a highly resilient, but undesirable state. If the system is transformed, it may occur via the drivers of inertia ('old' organizing principles) that remobilize industrial forestry ('inertia-transformed'); or to the other extreme, may occur via drivers of adaptation (to 'new' organizing principles) in response to political opposition to timber harvesting ('adaptive-transformed'). Neither of these system states will likely be resilient over the long term. We have already observed that the industrial forestry regime has not been sustainable, and conversely, it seems that a Tongass-wide moratorium on timber management would be unsustainable due to political and local economic interests, especially as second-growth forests regenerate to commercial size. A fourth scenario, in which the system remains largely stable but reorganizes to accommodate new conditions ('adaptive-stable'), involves reaching a settlement among land uses (including timber) that serves to ensure a balance among multiple-use interests. Such a compromise would ostensibly ease tensions and thus serve to reconcile the contentious and mistrustful atmosphere surrounding Tongass planning. A cooperative and flexible compromise among multiple-use interests, managed by the Forest Service, can foster a resilient and more desirable state.

While the timber issue remains highly contentious, the initial signs of cooperation among opposing parties are promising. The realignment of Tongass management into a more sustainable regime ultimately depends on the reconciliation of the conflicts among local and national stakeholders, their representatives, and the agency that manages their interests for the common benefit. It also may hinge on the willingness of Tongass managers to rethink some their most entrenched management concepts, such as clearcutting and the use of old-growth to achieve sustained-yield forestry. Presently the vast majority of Tongass timber funds are focused on the preparation and execution of timber sales (and the associated NEPA and litigation costs). The USFS could consider reallocating funds from traditional timber planning activities to a variety of forward-looking projects that improve second-growth forests and facilitate a modernized, flexible and value-added forest products industry in SE Alaska. The Tongass should also continue to implement adaptive management principles and improve the level of *a priori* stakeholder involvement in its planning process. A key research need is the description of the spatial and temporal patterns of resource production and demand, as a dynamic template for adaptive 'multiple-use' planning and decision-making.

More broadly, this means observing and responding to the recent dramatic changes in the SE Alaska economy and facilitating economic growth while conserving important biological and social values. The rapid growth of tourism and the guided recreation industry in the region provides an opportunity to do both, meanwhile intensifying the management of the existing second-growth timber base. As stewards of this future resource, in earnest cooperation with local and national stakeholders, the Tongass can transition into a more adaptive and sustainable management regime. In short, this means redefining the Forest Service interpretation of multiple-use in SE Alaska. As national leadership changes, the USFS-Tongass can strive to be the rational, scientific and adaptive institution that it was conceived to be, thus becoming a source of resilience at local, regional and global scales. In the words of Forest Service founder G. Pinchot, "[the] application of the conservation principle necessarily moved in different directions as one or another problem became important." As I have shown in this and the previous chapter, new problems and opportunities have emerged with shifting political, socio-economic, and ecological conditions at local, regional and global scales. In responding to these changes, the current reorganization period is a critical time for fostering a new regime of federal land management for the future social-ecological system of SE Alaska.

Table 5.1. Comparison of Tongass National Forest offers, sales and harvests to the Allowable Sale Quantity (ASQ), 1997-2005. Units are in million board-feet (mmbf).

Year	ASQ	Offered	% ASQ offered	Sold	% ASQ sold	Harvested	% ASQ harvested
1997	450	188	42%	202	45%	107	24%
1998	267	186	41%	24	5%	120	27%
1999	267	79	18%	61	14%	146	32%
2000	187	63	14%	170	38%	147	33%
2001	267	40	9%	50	11%	48	11%
2002	267	57	13%	24	5%	34	8%
2003	267	89	20%	36	8%	51	11%
2004	267	73	27%	87	33%	46	17%
2005	267	110	41%	65	24%	50	19%

Table 5.2. Tongass National Forest microsale program offers, volume and mean advertised rates, by species (2000-2005).

Species	# Offers	Total volume (thousand board feet)	% Total volume	Mean advertised rate (USD/thousand bd-ft)
Alaska Cedar	20	249.54	12.14%	145.3
Sitka Spruce	64	1130.27	55.01%	52.1
Western Hemlock	17	143.91	7.00%	7.6
Western Red Cedar	52	531.07	25.85%	42.0

Figure 5.1. Tongass National Forest harvest outputs from 1910-2005; divided into four stages of the adaptive cycle, as described in Chapter 4.

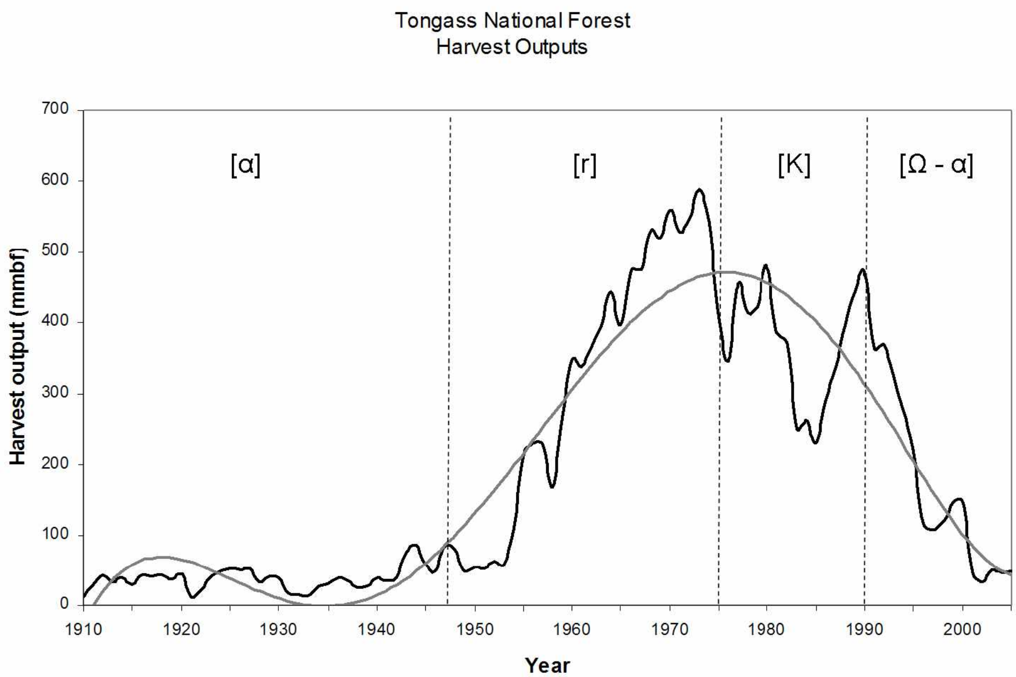


Figure 5.2. Trends in SE Alaska mill processing capacity and percentage utilization of that capacity (1981-2004).

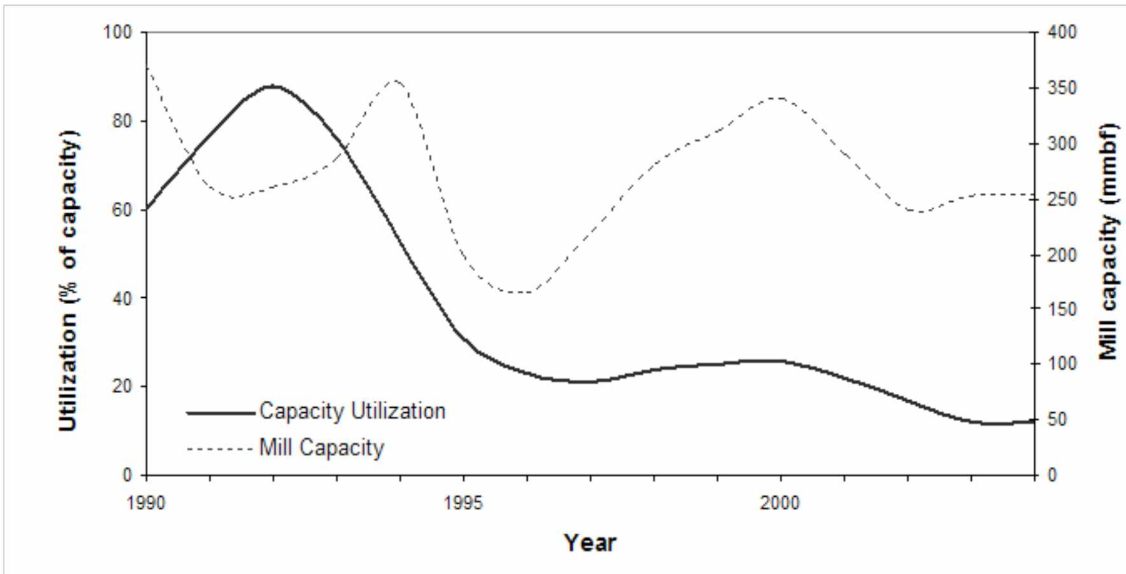


Figure 5.3. Tongass National Forest timber sale bids, average winning bid values and mean advertised rate of sale offers from 1990-2005. The left axis is the average number of bids per sale, per year. The right axis is the average winning bid value or the average advertised price, in US dollars (not adjusted for inflation).

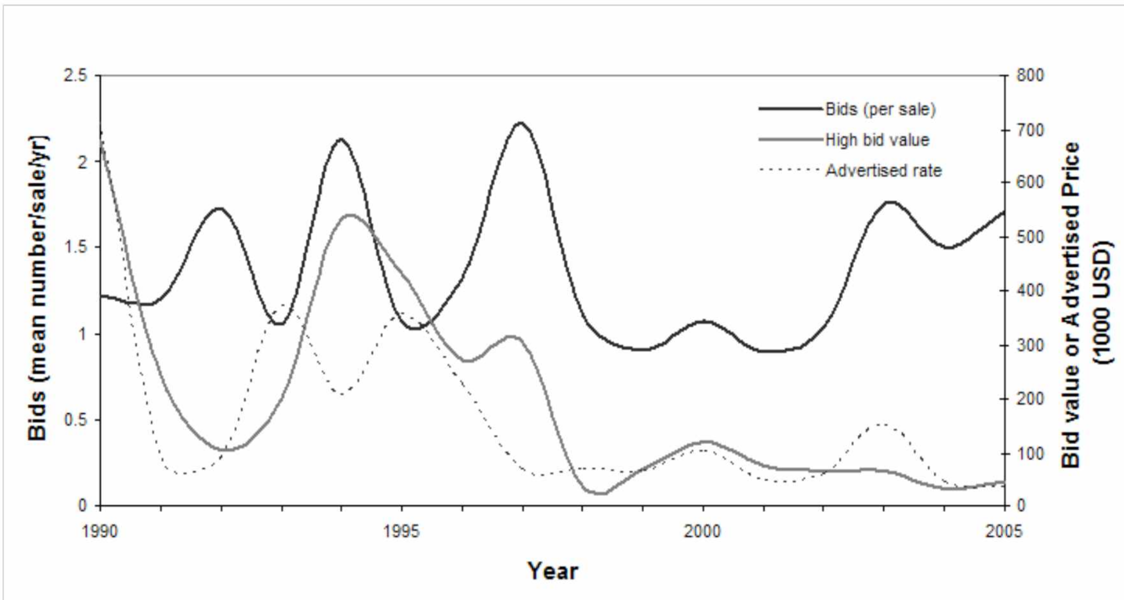


Figure 5.4. Mean advertised value of stumpage by species in Tongass National Forest timber sales (1990-2005).

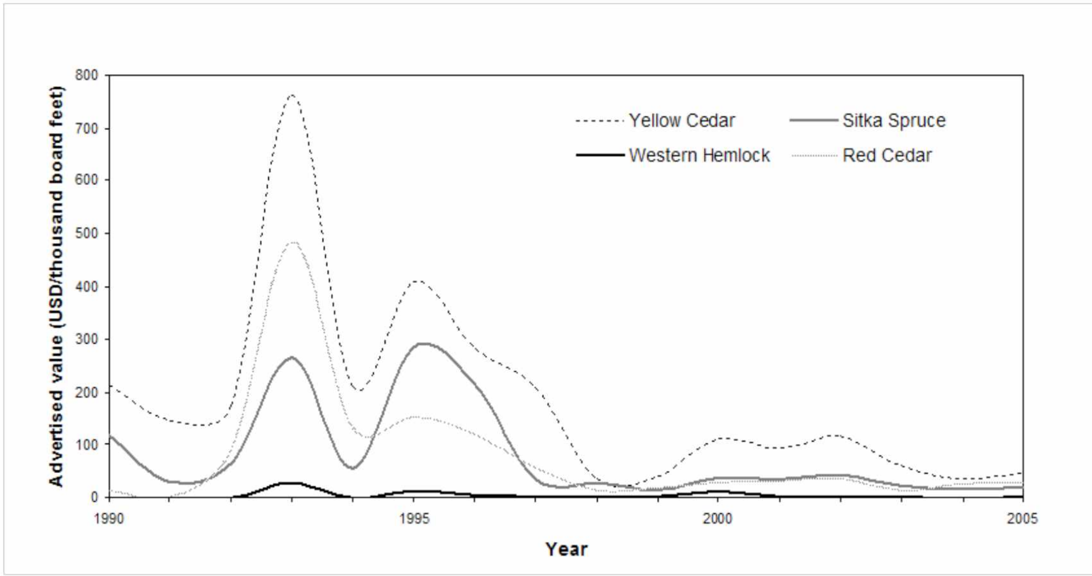


Figure 5.5. Tongass National Forest timber volume offered by species (1990-2005).

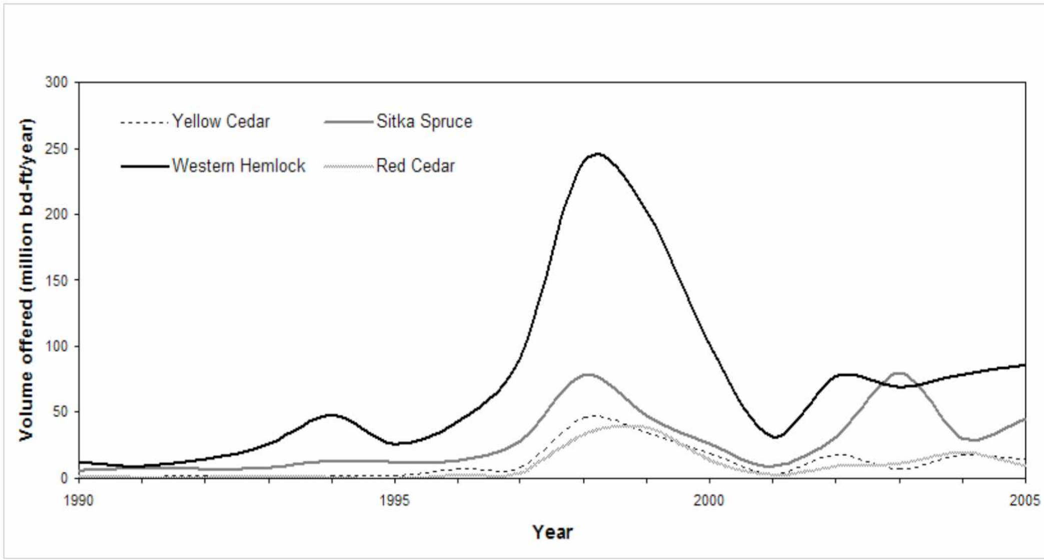


Figure 5.6. Ratio of pulp grade to saw grade materials offered in Tongass National Forest timber sales (1990-2005).

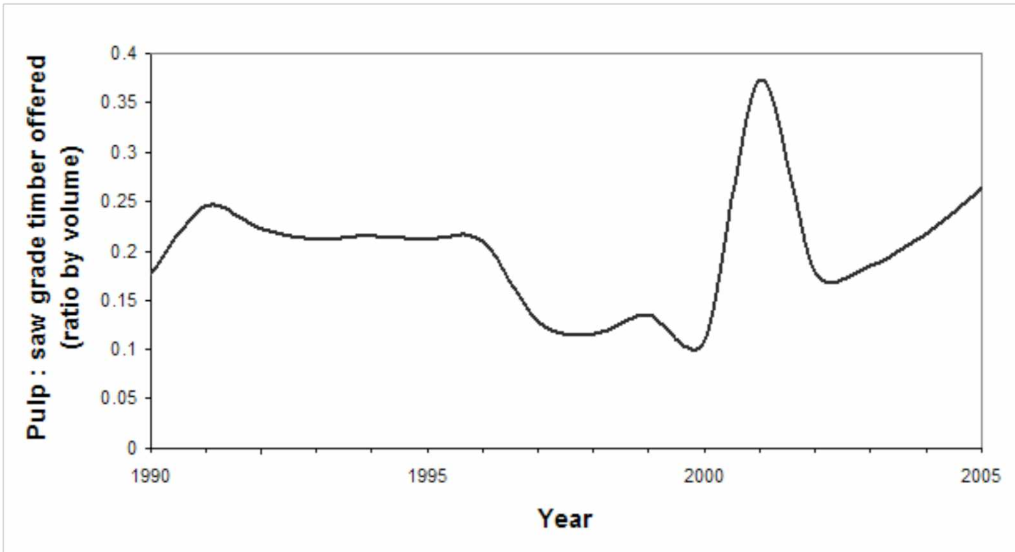


Figure 5.7. Area harvested by clearcut and selection methods in the Tongass National Forest, 1994-2004.

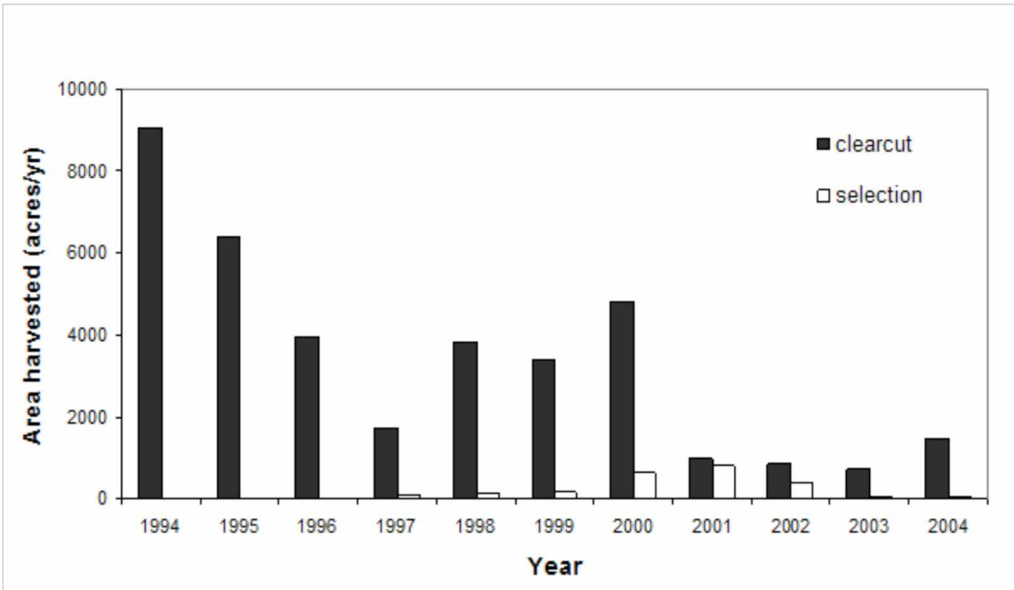


Figure 5.8. Types of sales offered (regular, salvage, microsale) on the Tongass National Forest (1990-2005). Note: the microsale program began in 1999.

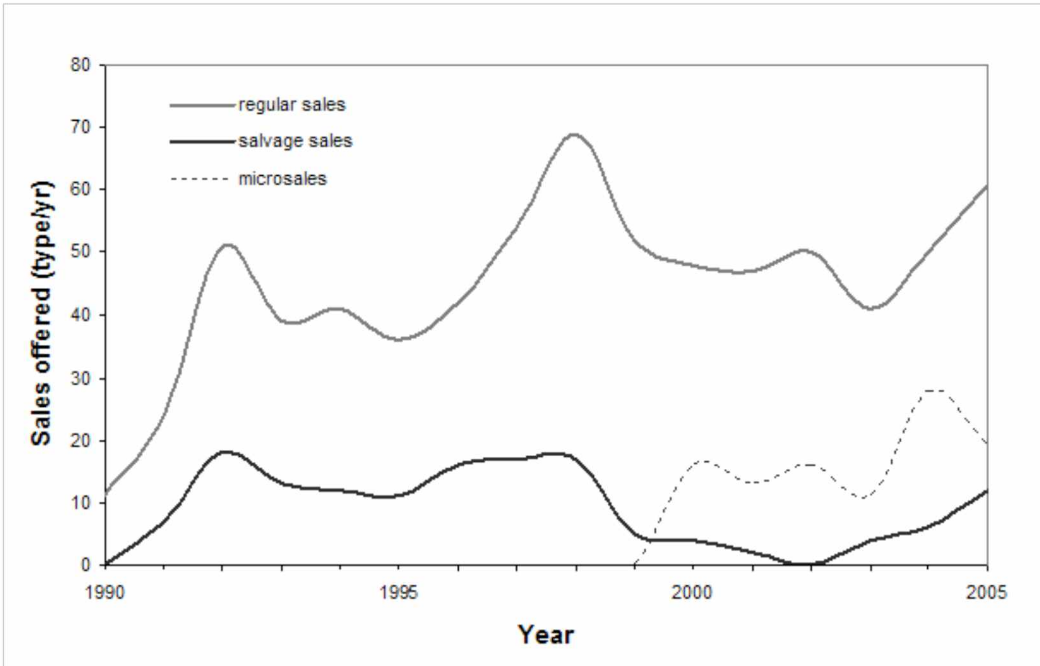
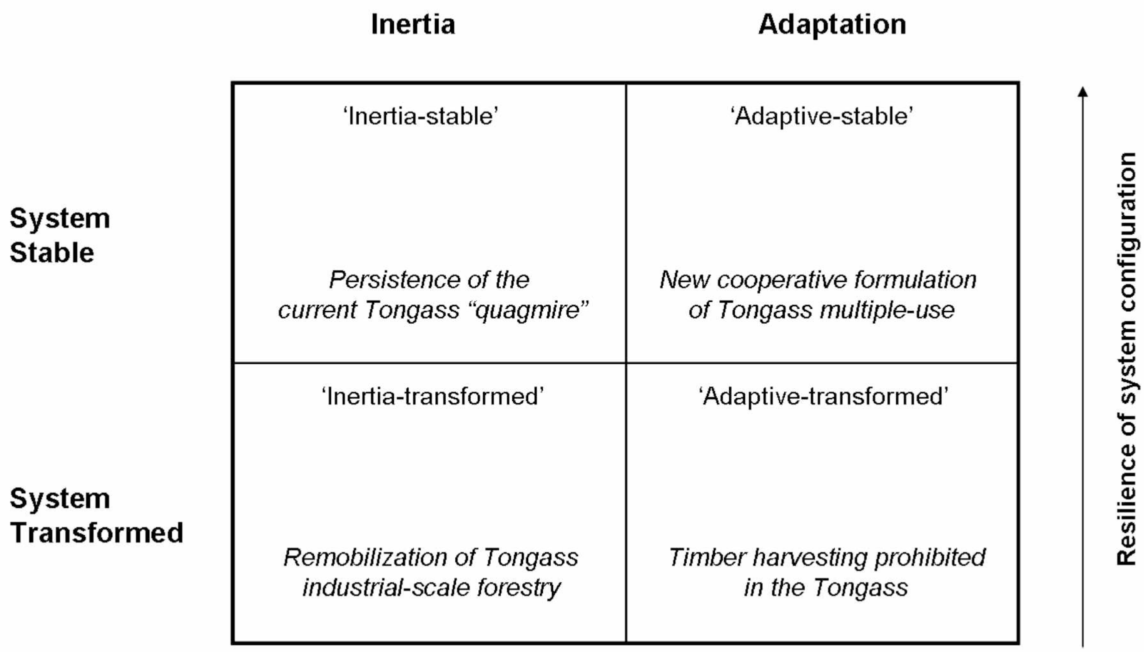


Figure 5.9. Reorganization scenarios, based on drivers (inertia, adaptation) and dynamics (stable, transformed) of the SE Alaska management system.



Chapter 6

Conclusions: regional dynamics and social-ecological resilience of Southeast Alaska

6.1 Summary

In this chapter, case study findings are synthesized to describe how the social-ecological system of Southeast Alaska has responded to multiple, converging drivers of change during the last century. Based on my case studies and additional research, I revisit the premise that regional climate and federal land management have been 'organizing components' of the SE Alaska social-ecological system (SES) and summarize how external drivers of change have influenced both factors during the 20th century. I found that these drivers of change - acting through climate and management - have resulted in the emergence of new and unprecedented phenomena, such as forest decline, and have driven long-term cycles of change, such as the boom-bust of the timber economy. The broader-scale responses of the Southeast Alaska SES to these dynamics are then described; in the case of cedar decline, I found that adaptive responses to emergent opportunities appear to be constrained by remnants of the past management system. To provide a measure of regional resilience, I present evidence of the response of the regional SES to the boom-bust cycle of the Tongass-supported timber industry.

An understanding of regional resilience also requires knowledge of the functional relationships within the SES. These relationships, or processes, dictate the flows of energy, materials, and knowledge among human and natural systems at multiple scales (Low et al. 1999). Given the strong ties of SE Alaska residents and economies to the natural landscape, I focused on the flow of ecosystem goods and services as a critical process in the SE Alaska SES. Using a new conceptual model and analytical framework developed for this research, I evaluated the integrity of these interactions with respect to the impacts of man-made disturbance regimes (e.g., timber harvesting and land cover change) on both the ecological provision and human use of fish/wildlife resources. Overall, I found that the retention of natural capital (e.g., capacity to produce resources) and social capital (e.g., capacity to use resources) in part supported a resilient transition of the SE Alaska SES in the years since decline of the timber industry. However, this analysis also identified areas of emergent vulnerability, where highly-productive and socially-important locales have been impacted by high intensity of man-made disturbance. These are places where current and future drivers of change may threaten the tight linkages between human and natural communities, which in turn may degrade regional resilience to future drivers of social and ecological change. I suggest that these locales should be management priorities in order to safeguard regional resilience, through research and mitigation of emergent vulnerabilities.

In concluding this research, I emphasize the current period of reorganization in Tongass management, where the future resilience of SE Alaska will be largely shaped by the course decided upon today. The capacity of management to afford regional resilience in the future requires a transition away from the stable, but undesirable, deadlock that it is currently experiencing. To this end, I outline three principle foci for the reorganization of Tongass management to face the issues and uncertainties of a rapidly changing world.

6.2 Climate change and emergent phenomena

The mild hypermaritime climate of SE Alaska is largely responsible for the structure, dynamics, and productivity of the temperate rainforests, which are globally rare. Unlike forests farther south, the SE Alaskan rainforests experience a climate with no prolonged or seasonal dry periods. As a result, stand-replacing fires in SE Alaska are rare and tend to be highly destructive. High precipitation throughout the year also maintains stream conditions necessary for the spawning migration of several anadromous fish species, including five species of Pacific salmon (*Oncorhyncus* spp.) that are 'keystone' elements of the SE Alaska SES. The region's strong maritime influence buffers against temperature extremes, resulting in a narrow and relatively stable range of mean temperatures throughout the year (compared to continental climates at similar latitudes) and therefore may also buffer against temperature increases associated with global change at high latitudes.

However, SE Alaska has warmed gradually since the end of the Little Ice Age circa 1880, as shown by this research and others (Viens 2001). For example, the five warmest years on record for Juneau (since 1914) occurred in 1987, 1993, 1995, 1997, and 2004. The case study of yellow-cedar decline (Chapter 2) suggests that high-latitude warming has changed winter weather in SE Alaska, leading to significant impacts on local ecosystems. Analysis of regional weather records suggests an increase in average minimum temperatures in SE Alaska, especially during the winter season, a pattern similar to that observed elsewhere at high latitudes (ACIA 2005). As a result, thaw conditions are occurring earlier, and more winter precipitation is falling as rain instead of snow. Indeed, the four lowest snowfall years on record (for Juneau records from 1948-2005) have occurred since 1986. The widespread dieback of yellow-cedar that appears to be caused by warming-induced changes in winter climate may be an early signal of forest dynamics in response to global change.

While this signal has been limited to a single species primarily in low elevation forests, it suggests the potential of a broader vulnerability of coastal forests in the region. Yellow-cedar is commonly regarded as the most stress-tolerant and longest-lived tree species in Alaska (D'Amore and Hennon 2006); however its early-growth characteristics, in combination with warming winter conditions, appear to make the species vulnerable to episodic injury and mortality (Chapter 2; Hennon et al. 2006). These characteristics probably afforded a competitive advantage for yellow-cedar during the Little Ice Age, but are now poorly adapted to modern climatic conditions, at least at elevations near sea level. It is uncertain whether other tree species in SE Alaska possess this type of formerly beneficial, currently maladaptive trait. Moreover, the prevalence of cedar dieback in low-lying, poorly-drained forests suggests that other species occupying these site types may be vulnerable to a similar type of injury (although no evidence currently exists). If so, this could strongly influence regional ecological processes because these muskegs and forested wetlands account for approximately one-fourth of SE Alaskan forests.

Post-Little Ice Age climate change has also altered other dynamics in SE Alaska ecosystems. The establishment of productive Sitka spruce forests on uplifted beaches and recently deglaciated terrains has resulted from post-Little Ice Age glacial recession. Anecdotal observations suggest the expansion of bog-muskeg complexes in low-lying forests, potentially resulting in the loss of forest productivity and widespread tree mortality in the areas of expansion. For example, in the course of the cedar research I observed several areas of non-specific forest decline (e.g., involving all species present at the site) that appeared to result from expansion of poorly drained soils. These boggy conditions and associated non-specific tree mortality also appear to occur in valley bottoms below clearcut-harvested forest slopes (based on my preliminary observations). This suggests that clearcut harvesting may alter the hydrology of adjacent forests. Studies are needed to determine if these processes are linked. If so, there could be important interactions between climatic and management drivers of change, resulting in reduced productivity and/or tree mortality in areas adjacent to stands that are managed for timber.

Finally, the occurrence of uncharacteristically warm and dry summers in recent years (2003-2005) could have negative impacts on forests (e.g., increased fire risk in a rainforest poorly adapted to fire) and anadromous fish streams (e.g., reduced stream levels and water quality). Although these recent occurrences do not yet represent a definitive trend in weather records, the linkage of SE Alaska climate to larger scale atmospheric and oceanic circulation patterns (e.g. the Pacific Decadal Oscillation and the El Niño phenomenon), which are driven by global climate processes, suggests greater uncertainty in summer weather in SE Alaska than in the past. In the summer of 2005, local residents in many areas of SE Alaska reported fish kills in lower stream reaches (downstream of spawning grounds), ostensibly due to low water levels and high water temperatures. Other extreme conditions in SE Alaska climate may have negative impacts on wildlife populations. For example, while low snowfall may present a risk factor in forest decline, unusually heavy snowfall in the early winter months may have deleterious impacts on Sitka black-tail deer, especially in deforested areas. Heavy snowfall in early winter may also increase hunter harvest, because deer tend to move into coastal areas where hunting is easier (Hanley et al. 2005).

Although the ecological and social impacts of climate change are poorly understood in SE Alaska, the observations summarized above suggest a high vulnerability. In general, vulnerability to climate change reflects both sensitivity to change (Turner et al. 2003), which appears to be high in SE Alaska, and exposure to change (Adger 2006), which is uncertain but appears to be increasing. Potential feedbacks from land cover change, forest decline, or glacial recession to the regional climate have not been investigated. In general, these are thought to be relatively minimal, given the large proportion of unmodified landscape and the importance of terrain and geographic location in dictating weather patterns. At present, scientists and managers are only beginning to observe direct effects of regional warming on the SE Alaska SES.

6.2.1 Social response to cedar decline: a missed opportunity?

Dynamics of change in complex systems often drive the emergence of unprecedented or unpredictable phenomena, in the form of new conditions, cross-scale linkages, or controls over system function and resilience (Gunderson et al. 1995; Carpenter and Brock 2004; Walker et al. 2004). In social-ecological systems, emergent phenomena can present both challenges and opportunities to landowners, residents, and resource managers (Berkes et al. 2003). As an emergent phenomenon of climate change in SE Alaska, yellow-cedar decline presents both a challenge (to fully understand its cause and its potential spread) and an opportunity (to salvage the highly valuable timber to support local industry). There are over 300,000 acres of declining and standing dead cedar across SE Alaska, which remain highly valuable because of the unique decay-resistant qualities of yellow-cedar heartwood (Hennon et al. 2005). High local demand for yellow-cedar wood is evidenced by the fact that nearly all cedar salvage offers are competitively bid upon and sold. Yellow-cedar is currently the most valuable species in Alaska, with a price per board-foot about three times that of the next most valuable species, Sitka spruce (*P. sitchensis*).

Given the integral role of the Tongass in supplying the regional timber industry, and the political pressure on forest managers to offer sufficient timber to meet local demand (Repetto 1988; Nie 2006; USDA 2003), it would seem that small-scale salvage of highly valuable wood would be an ideal short-term measure. Salvage sales are more easily justifiable from a forest health perspective and can bypass certain NEPA requirements, and therefore are less likely to receive significant legal opposition. Market conditions have shifted in recent decades to improve the cedar salvage opportunity; prior to 1984, most yellow-cedar in clearcut units was not brought to market, because of a lack of perceived demand. Current market prices for yellow-cedar lumber, while lower than their peak in the 1990s, probably provide a sufficient margin to allow for local value-added processing. Moreover, in efforts to improve market position and premiums of cedar lumber, the US Forest Service has invested millions of dollars into research and marketing of the unique properties of the wood. Since the convergence of these factors has coincided with the decline of the regional timber industry, the emergence of this opportunity during the last two decades seems auspicious.

Yet, my analysis of timber sale planning trends (Chapter 5) found that Tongass managers have not taken advantage of this emergent opportunity by significantly increasing the availability of cedar through salvage offers. Tongass managers have been reluctant to increase the salvage of dead yellow-cedar because the practice will greatly reduce the value of large clearcut units that are scheduled for future harvest. In this sense, the continued importance of clearcutting and large-scale production forestry philosophy keeps the high-value cedar snags in the forest, instead of in the local mills. Thus the persistence of management approaches and philosophies (which were institutionalized over sixty years ago) has constrained the broader social-ecological system in its response to the emergent cedar opportunity. Moreover, I suggest that the lack of a response to the cedar salvage opportunity may be an indicator of a general inability of Tongass management to respond adaptively to emergent phenomena. If managers are reticent to take advantage of a situation that would simultaneously address policy mandates, support local economies through timber production, and potentially improve forest health, then it can be argued that other emergent factors, especially those not associated with economic benefit or achieving management objectives, will receive less attention. As a result, and because of the jurisdictional dominance of the Tongass in SE Alaska, the adaptive capacity of the broader SES may be constrained in the face of future change.

6.3 Forest management and social-ecological resilience

As the dominant landowner in the region throughout the 20th century, the Tongass National Forest has exerted influence on both ecosystem structure/processes, and the patterns of human settlement/resource use in SE Alaska. Since 1908, the Tongass has controlled over three-fourths of the region's land area and has shared principal authority over public land management with only two other major agencies (the AK Dept. of Fish and Game and the National Park Service). Since nearly all communities in SE Alaska are separated by vast distances, island geography, and the absence of an integrated road network, these communities exist as 'islands' within a 'sea' of

National Forest land. As a result of this enveloping influence, nearly all land-use decisions in SE Alaska have involved the Tongass and US Forest Service in some way. Moreover, the 20th century emphasis of Tongass land management - production forestry to supply a timber industry - has influenced current and future ecosystem conditions, land uses, and social values for the nearly 500,000 acres of managed forests in the region.

At different periods during the 20th century, the Tongass has been a source of stability and resilience, as well as instability and vulnerability. As discussed in detail in Chapter 4, Forest Service management fostered a timber-dependent economy that experienced a boom-bust cycle in response to external drivers of change. In the first four decades of Tongass management, the concept and approach to forest management were founded. With key policies and post-war economic conditions providing positive feedbacks, long-term leases were created and the system rapidly mobilized and grew. As it grew, however, the national political landscape gradually shifted, resulting in environmental protections and institutional reforms that, in sum, served to open new venues of decision making to challenge Tongass management. For a period of time, the Tongass policy monopoly resisted these external perturbations by protecting the long-term leases, a behavior clearly apparent in the negotiations surrounding the wilderness designations of ANILCA (Chapter 3). Meanwhile, market conditions for Alaskan timber and pulp declined, and the processing infrastructure in the region became technologically outdated and inefficient. Despite deteriorating infrastructural and political conditions, the long-term leases stabilized the industry, to a degree, during market downturns of the 1980s. When the lease subsidies were greatly weakened by the Tongass Timber Reform Act, the industry collapsed in response to a second market downturn of the 1990s. With the closure of regional mills, many communities suffered economic hardships - through loss of employment and municipal tax revenues - that continue to the present day. Market conditions have improved, yet the remaining industry operates at only about ten percent of its current capacity. By the year 2000, harvests of Tongass timber had returned to the pre-industrial levels of the early 20th century.

As briefly discussed in Chapter 4, the Tongass story epitomizes the "pathology of resource management" described by Holling (1986) and Holling et al. (2002). In hindsight, the weaknesses inherent in the management regime become clear. However, it is important to recognize that national policymakers and Tongass managers had the best intentions upon setting this course in SE Alaska, and the region benefited significantly for several decades from the industry that was created. The sustained yield management approach and pulp industry were rational decisions for SE Alaska at the time, given the shared beliefs about the undesirability of old-growth forests and the need for a regional economic base. Since its creation the Forest Service has been served by some of the most highly educated and well-trained civil servants of any federal agency (Rakestraw 1989; Steen 2004). These individuals were not single-minded "timber beasts" but instead advanced some of the most progressive management practices of their time, as many managers of National Forests still do. In establishing the Sustained Yield Forest Management Act of 1947, the Forest Service codified the sustained yield forestry school-of-thought, the most systematic and forward-looking approach to timber management at the time. Moreover, USFS managers were among the early vanguard of the conservation movement, and created some of the largest wilderness areas in the United States, decades before the Wilderness Act of 1964 required this measure. Thus we cannot blame the resulting management pathologies that occurred on the Tongass and other timber-producing National Forests in the Pacific Northwest (Trosper 2003; Steen 2004) on an incompetent, unscientific, or an entirely 'myopic' institution. How then did this pathology occur in the case of the Tongass?

In short, traditional disciplinary perspectives and their application in resource management tend to generate actions that are unsustainable (Light et al. 1995; Holling et al. 2002; Berkes et al. 2003). In the Tongass, the 'timber solution' was intended to solve the ecological, economic, and social problems as they were defined at the time. Three central principles founded the Tongass approach: sustained-yield forestry, economic subsidization, and policy monopoly. While seemingly very different concepts, these approaches share two important features: they attempt to constrain the inherent variability of a system; and they poorly account for external drivers of change and uncertainty. For example, the implementation of sustained-yield forestry requires the creation of even-aged stands to be managed on a rotational basis, with the expectation that second-growth forests will regenerate to their prior condition. An implicit assumption of this approach is that ecosystems have a stable equilibrium and that natural variability can be constrained to maintain a desired stable configuration. Ecologists and systems theorists have increasingly shown that this is a faulty and often dangerous assumption, especially in ecosystems experiencing other drivers of change (Holling 1986; Walker et al. 2004).

The sustained yield approach has repeatedly proven to be unsustainable, whether it is applied to forests, fisheries, agriculture, or for other purposes (Repetto 1988; Light et al. 1995; Berkes and Folke 1995; Holling et al. 2002; Trosper 2003). In many cases, the resulting depletion of resources (and degradation of the provisioning ecosystems) generates the destabilizing feedbacks that collapse the management system (Gunderson et al. 1995; Berkes et al. 2003) and, in some extreme cases, lead to collapse of the larger social-ecological system (Diamond 2005). Yet in the case of the Tongass, I suggest that the sustained yield approach, despite its inherent weaknesses, was not the primary driver of destabilizing change in the management system of SE Alaska. Ecological feedbacks on the timber production regime were largely positive, because rapid regeneration of even the largest harvest units in SE Alaska suggested the continued productivity of the forest ecosystem. Moreover, to the present day, there is little 'hard' scientific evidence to suggest that the broader impacts of logging have led to irreversible ecological degradation in SE Alaska (Hanley et al. 2005).

Instead, the drivers of collapse and transformation in Tongass management largely arose from external social changes, related to the environmental movement and declining market conditions (Chapter 4). These shifts resulted in the well-documented management conflicts and economic declines in the timber-producing National Forests of the U.S. Pacific Northwest in the early 1990s (Trosper 2003). Indeed the Tongass was swept up in the broader national debate symbolized by the Northern spotted-owl controversy in Oregon and Washington (Wilkinson 1997; Nie 2006). However, while the concern over endangered species reflected direct observations of ecological degradation in the Pacific Northwest, this type of phenomenon had not been observed in SE Alaska at the time. But environmental advocates who opposed industrial forestry in the Tongass used this ecological argument extensively (Malmsheimer et al. 2004). In essence, opponents of logging sought to prevent a similar outcome in SE Alaska (Nie 2006) and were largely successful. Their influence acted as a cross-scale feedback, and as a result, the management regime of SE Alaska is now strongly shaped by environmental interests.

6.3.1 Regional resilience to timber industry decline

While scholars and managers agree that collapse of the timber industry had major ramifications for SE Alaska, and that tourism-related activities have expanded in the 'vacuum' left behind by timber (Allen et al. 1998; USDA 2001; USDA 2004; Nie 2006), there is conflicting evidence with respect to the economic impacts of mill closures in SE Alaska communities. An understanding of these impacts is important for assessing regional resilience in the current economic transition.

Although employment losses were concentrated in the mill towns of Sitka, Ketchikan and Wrangell, all SE Alaska communities experienced declines in revenues arising from Tongass timber receipts. By the 1980s, these revenues had largely replaced state funds as the primary source of external support for public schools in SE Alaska communities; as a result, from 1990-1996, declines in spending per student were observed in nearly all communities (Allen et al. 1998). However, at the regional scale, one study found no statistically significant or consistent negative economic impacts of mill closures across all SE Alaska communities (Robertson 1999). A study commissioned by the Forest Service suggested (mostly on a qualitative basis) that $130 million in federal relief funds[13] were essential for economic recovery in communities like Wrangell, which received nearly one-third of the funds (Allen et al. 1998). Other research suggested that the appropriation of these funds was more of a political maneuver based on exaggerated estimates of the negative impacts of mill closures (Durbin 1999; Nie 2006). While the importance of federal relief funds in SE Alaska is debatable, overall population and employment trends have remained stable throughout the period of timber industry decline (Crone 2004).

Community-level resilience to timber industry decline is not well understood, in part because of the differences among local economies and, in particular, the variability in their prior dependence on timber-related revenues and employment. In general the communities in the northern areas of SE Alaska (with the important exception of Haines) were less involved in the timber economy. In southern areas, larger communities like Wrangell, Sitka, and Ketchikan - as well as many smaller settlements and towns in the heavily-logged areas of Prince of Wales Island - lost their largest single employer when the major mills closed. As mentioned above, the mitigating impact of federal relief funds confounds the analysis of community resilience to an unknown degree. Quantitative indicators alone fail to capture the important changes that have occurred (Tromble 1996; Gilbertsen 2003) and provide little insight on why some communities were more resilient than others. At present, the best insights on resilience have come from case studies comparing communities since mill closures (Allen et al. 1998); excerpts from these case studies are below:

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[13] Southeast Alaska Economic Fund; Balanced Budget Down Payment Act of 1996 [Public Law 104-134]

> Sitka lost its largest employer when the APC pulp mill closed in September 1993. This was not just a major loss in employment, but in income; the mill jobs, on average, paid 84 percent more than other wage jobs in Sitka (Lane 1994). Employment in construction, wholesale trade, and transportation industries declined as well when the mill closed. School enrollment showed a decrease in the two subsequent years, as did population, which remains below the 1993 level. Housing prices have continued to increase and rental prices, although fluctuating, have not dropped; vacancy rates remain slightly higher than in 1993.
>
> Another case study is provided by Wrangell, where the APC sawmill, which employed 225 people and accounted for 23 percent of the wage and salary jobs and 30 percent of Wrangell's payroll wages (Boucher 1994), closed at the end of 1994. The impact of losing its largest employer spiraled through Wrangell, with declines in wholesale trade, transportation, service, and financial-insurance-real estate sectors. City sales tax revenues fell 12 percent from the first quarter of 1994 to the first quarter of 1995, compared to previous annual increases of about 4 percent (Tromble and Boucher 1995). School enrollment decreased and rental vacancy rates increased substantially.

According to studies commissioned by the State of Alaska, Sitka has "weathered its loss surprisingly well" (Tromble 1996) in part because it "benefits from having several year-round institutional payrolls" (Smith 1996). In other words, a diversified economy has helped Sitka adjust to major economic changes. Moving forward, Sitka's governance and leadership have expanded this diversity while harnessing the rising surge of tourism and amenity migration. Population declined immediately after mill closure, but stabilized at approximately 95% of its previous peak (in 1993). Overall number of jobs has increased, particularly in service and real estate sectors, while the core sectors in Sitka (e.g., health care, seafood processing, education, and government) have remained strong (Gilbertsen 2003). Sitka has also become a 'hotspot' for amenity migration and, as a result, has the fastest growing property values in the region (Crone 2004). Community leadership has also been forward-thinking and innovative; e.g., by 'recycling' the Silver Bay APC pulp mill facility into a vocational training center and a commercial water bottling plant. For these reasons, Sitka is probably the best example in SE Alaska of community resilience since the mills closed.

Wrangell, on the other hand, lacked the population size and economic diversity of Sitka, and has struggled to revitalize its local economy (Allen et al. 1998). Despite the considerable aid provided by federal relief funds, the town continues to face economic stagnation, although the opening of a new sawmill (Seeley Forest Products) has engendered some local promise for the future. Population in the Wrangell-Petersburg census area has continually declined since 1990. Most of this decrease has been attributed to former mill workers (and families) leaving Wrangell, while Petersburg (mainly a fishing community) was largely unaffected by the timber boom-bust cycle in SE Alaska (ADOL 2003). Wrangell has not seen the tourism boom like many other towns and villages in SE Alaska, in part because the town opted out of cruise ship visitation during the 1980s.

Tourism appears to have a promising future for growth in SE Alaska (Colt 2006), but it is unclear whether tourism jobs (that are mostly low-wage and seasonal) are equivalent to the high-wage, year-round timber jobs that they "replaced." Nor is the tourism industry less vulnerable than the timber industry to external perturbations, although the drivers of change will likely be different. It is unlikely that tourism will engender the magnitude of conflict related to timber development, and thus may not be as vulnerable to the political drivers of change that have reshaped land management in SE Alaska. However, some areas important for ecotourism are undergoing rapid climate-related change; most notably the recession of the coastal glaciers in popular and iconic landscapes like Glacier Bay National Park. Tourism is arguably more sensitive to national economic conditions and public perceptions of transportation safety (especially in recent years) than the timber industry (Crone 2004). Thus overall, it is unclear whether tourism as an economic base affords any greater degree of resilience in the regional SES, relative to the historical timber economy.

6.4 Integrity of natural and social capital

The preceding synthesis of case studies provided insights into the dynamics and resilience of SES components (climate and management); this section addresses a key interaction among social and ecological systems in SE Alaska. Social-ecological interactions can be described in terms of bidirectional flows between natural and social components; these flows and the underlying functions that drive them can also be thought of as the 'processes' of the SES (Low et al. 1999). To describe social-ecological interactions in SE Alaska, I focus on two types of flows: first, the flow of goods and services from ecosystems to society, involving the processes of provision (by ecosystems) and receipt/use (by humans), and second, the flow of human modifications of ecosystems for social and economic objectives, involving the processes of anthropogenic disturbance and ecosystem responses to change. My central premise is that the flow of human modifications (e.g., disturbance) can alter the flow of ecosystem services and its associated processes (e.g., provision and use).

Human modifications of ecological systems often generate landscape changes that deplete or transform natural capital (Holling et al. 1995; Carpenter and Brock 2004). This in turn erodes society's options by depleting the resources (ecosystem goods) that are valuable to people through the production process; and by degrading ecological functions (ecosystem services) that cannot be imported or substituted by human means (de Groot 1992; Collados and Duane 1999). To utilize natural capital, people often modify disturbance regimes by stabilizing key ecological processes, leading to a loss of ecosystem resilience (Gunderson et al. 1995; Walker et al. 2006).

When the loss of resilience threatens the existing configuration of ecosystem goods and services, vulnerabilities may emerge in social-ecological systems (Light et al. 1995; Gunderson and Holling 2002). In this way, the feedbacks from anthropogenic disturbance often become limiting or transformative factors in societal development (Deutsche et al. 2003), with outcomes ranging from resource conflicts to boom-bust cycles to the collapse of entire civilizations (Berkes and Folke 1998; Redman 1999; Berkes et al. 2003, Diamond 2005). The difficulty, however, is that we seldom know what places are most vulnerable until after the degradation has occurred.

To this end, I present a conceptual model of anthropogenic disturbance as a driver of change in the provision and receipt of essential goods and services to society. I apply these concepts in an analytical framework based on three multifactor criteria: ecological provision (of goods and services), human use of these services, and disturbance, which can disrupt the connection between provisioning and use. In theory, the nexus of these factors is where I expect social and ecological components to interact most strongly and therefore where social-ecological resilience may be constrained by human disturbance. I apply this model in an analysis of the SE Alaska landscape to provide several measures of resilience and vulnerability of the regional SES. Here rural residents depend on subsistence and commercial uses of 'wild' resources, but many of the watersheds where these resources are produced and harvested (or used) have been modified by four decades of intensive timber management. Using locally appropriate indicators, I mapped areas where high fish/wildlife productivity, high human use, and high timber-related disturbance coincided on the landscape. These are locales where unintended and/or unpredictable consequences of disturbance may generate undesired outcomes and vulnerability.

The underlying premise is that the Tongass, as the dominant landowner and regulatory authority in the region, manages how ecosystem goods and services are provided and used in the regional SES. I show that vulnerabilities in ecosystem services may emerge due to the legacy of the past management regime of industrial production forestry. Given the critical role and influence of the Tongass in the region, I argue that these vulnerable locales should be management priorities to ensure sustained flows of goods and services to local residents, visitors and major economic sectors. Based on this analysis, I provide several proxy measures of social-ecological resilience at the watershed and regional scales. I also assess the role of SE Alaska land use policy, such as the conservation measures of ANILCA, in shaping current and future regional resilience.

6.4.1 Conceptual model of social-ecological interactions

The model of social-ecological interactions is described below and in Figure 6.1. Ecosystems (as natural capital) generate goods and services that drive economic production of market commodities, provide non-market services and amenity values, and support the maintenance of the conditions necessary for human well-being (MEA 2003). Human management of natural capital often emphasizes commodity production (which is a subset of goods/services provided) through the regulation of ecosystem functions to serve economic and/or social goals. These land uses are often accompanied by land cover change, the introduction of a different disturbance regime (e.g., a timber harvest rotation based on maximum sustained yield) and other potential impacts (e.g., introduction or removal of species). In the absence of restorative measures, these human actions can feed back to the ecological capacity to provide future goods and services to society, as well as the social capacity to acquire certain resources. For example, in a landscape managed for timber production, harvest of productive forestlands may reduce the provision of other goods and services provided by undisturbed old-growth forests. Conversely, increased road access and altered scenery may affect human preferences for subsistence and/or recreational use. In cases of either severe or persistent anthropogenic disturbance, the degradation of social-ecological resilience – to future human and natural disturbances – may precipitate a shift into alternate configurations of provision and receipt (Gunderson

2000; Holling et al. 2002). Goods and services that are no longer provided in the new configuration may not be restorable or substitutable at relevant scales by human means (Ludwig et al. 1993; Collados and Duane 1999).

6.5 Methods

To apply this model, I developed an analytical framework with two requirements in mind: first, to explicitly describe the spatial patterns of ecosystem provision, human use, and man-made disturbance, using existing data sets; and second, to be able to integrate this information at relevant scales and in locally meaningful ways. Using expert knowledge of the region, I chose groups of indicators to populate the three criteria used to evaluate the integrity of ecosystem services in SE Alaska: *provision* of fish/wildlife, *use* of fish/wildlife, and *disturbance* from timber management. I then constructed a social-ecological geographical information system (GIS; ESRI ArcView 3.x) based on available datasets with full regional coverage. A criteria-and-indicators method was used to aggregate data at the watershed unit; this involves the summary of a large group of data elements (indicators) to evaluate a small number of categories (criteria) for each unit(s) of interest (e.g., watersheds). The limitations of existing data required several assumptions and the use of proxy measures in the subsequent GIS-based analysis. Each SE Alaska watershed (n=1006) was then ranked according to *provision*, *use*, and *disturbance* criteria, providing a basis for determining where logging disturbance is spatially coupled with the most important locales for fish and wildlife production and harvest in SE Alaska. An explanation of each step follows.

6.5.1 Criteria and indicators

I employed the 'criteria and indicators' approach in order to aggregate multiple data sources (indicators) into a small number of indices (criteria) that could be compared in a spatially-explicit manner. Taken individually, I do not intend that any single criteria or indicator is a measure of vulnerability or resilience; unlike the applications of the approach in "sustainability assessments" such as the Montreal Process (Canadian Forest Service 2001). Criteria are based on my conceptual model, in order to demonstrate its application. Indicators were chosen based on the specific objectives of our assessment, expert knowledge of the case study region, and existing datasets. I chose to focus on provision and use of fish and wildlife, because of the local importance of these resources, and the concern over the impacts of logging and roading in the forested watersheds of SE Alaska and their biological resources.

6.5.2 Human use

Residents of SE Alaska engage in a variety of subsistence practices that range in significance from minor food supplements to primary sources of foodstuffs and heating fuel. In the thirty-two rural communities of SE Alaska, annual gross subsistence harvest is approximately 5.8×10^6 lbs (2900 tons), equivalent to 271.2 lbs per capita, not including firewood (ADFG, *unpublished data*). These resources include wild game, fish, seafood, plant foods and other non-timber forest products. For many rural residents this harvest provides the majority of their protein intake and supplements their heating fuel (firewood) needs. Subsistence foods are a basis for trade and supplemental cash income, as well as a critical source of cultural identity and community resilience. The subsistence lifestyle is integral to the social identity and cultural heritage of Alaska Natives, whose traditional hunting and gathering practices are passed through oral tradition. In Alaska, subsistence opportunities contribute in non-material ways to the quality of life for all residents regardless of heritage. Federal law also requires that all managing agencies maintain subsistence access and, in cases of resource shortages, mandates the priority of subsistence.

Several regional industries depend directly on fish and wildlife populations supported by the ecosystems of SE Alaska. First, the commercial production, processing and distribution of fish and seafood resources constitute a major sector of the SE Alaska economy. Commercial fisheries are a major source of employment and revenue in several communities that have large commercial fleets and processing operations (e.g. Petersburg, Ketchikan, Juneau, and Sitka). Sectors of the tourism and visitor industry also depend directly on fish and wildlife populations, for both consumptive and non-consumptive uses. Visitor sport fishing and hunting supports the guide/outfitter and ecotourism industry; which depends on the availability of fish and wildlife species for harvest or observation in their natural habitat. Nature-based recreation/ecotourism is the fastest growing industry in SE Alaska, comprising approximately ten percent of the regional economy (Colt 2006).

6.5.3 Anthropogenic disturbance

The potential ecological impacts of timber harvest in SE Alaska are not well understood, largely because disturbances of this type and spatial magnitude have no natural equivalent or historical precedent in these forests. While it appears that most harvested stands have initiated rapid regeneration, too little time has passed to understand impacts that may occur over the medium to long term. Long periods of regeneration (100-250 years) are required for second-growth forests to attain old-growth condition, which is considered the optimal habitat for most terrestrial fauna (Hanley et al. 1989; Hanley et al. 2005). During regeneration, the structure of dense young forest excludes understory browse vegetation (Deal 2001) and lacks the unique habitat requirements of several endemic species (DeGange 1996; Hargis et al. 1999; Willson and Gende 2000).

Timber management also has putative impacts on the aquatic habitats of endemic fish populations, including the spawning and rearing grounds of anadromous salmonids. Harvesting of riparian forests alters stream habitat due to increasing light penetration (Meehan 1970; Tyler et al. 1973), changes in stream chemistry (Singh and Kalra 1977), reduced large woody debris input (Chamberlin 1982), increased sediment loading due to runoff and soil erosion (Brown and Krygie 1971; Swanson and Dyrness 1975; Beschta 1978), and changes in fluvial geomorphology (Wood-Smith and Buffington 1996). Outside of the riparian zones, impacts of timber management on hydrological and nutrient cycles – two closely coupled processes in these highly mesic forest soils – can degrade stream habitat even if riparian zones remain undisturbed (Chamberlin 1982).

6.5.4 Geographic information system

The Southeast Alaska GIS incorporated all available spatial data pertaining to ecosystems, human uses and anthropogenic disturbance. I only included data layers with complete regional coverage in the GIS; coverages and data sources are described in Table 1. Several types of spatial datasets were incorporated in the GIS: polygon, point, and line themes, grid coverages, and watershed attributes. All polygon and grid themes were converted to uniform $250m^2$ grid coverages. These grid coverages described the spatial arrangement of either a continuous element (e.g. stand volume, habitat suitability) or a discrete categorical element (e.g. species presence/ absence, land cover type, riparian zone). Watershed attribute themes described certain characteristics where the finest resolution available was at the watershed scale. Nearly all available spatial data on human use intensity in SE Alaska were in this format (e.g., hunting and sport-fishing use).

6.5.5 Assumptions and data proxies

A major challenge in evaluating ecosystem services and understanding disturbance-related vulnerability lies in the integration of social and ecological information across space and time (Carpenter and Brock 2004). Ecosystems and human systems are not static over time, nor are they uniformly distributed across the spatial landscape. Likewise, ecosystem services are supplied and received at a range of spatial and temporal scales (Limburg et al. 2002), from the short-term, local scale (e.g., fisheries) to the long-term, global scale (e.g., climate regulation). To resolve these complexities for analytical purposes, I made several assumptions to simplify the spatial and functional linkages among ecosystems, habitat, human uses, and land-use disturbance.

First, I considered only the processes that were sufficiently local in scale to differentiate among watersheds, because only these indicators would influence watershed rankings. Secondly, I treated watersheds as individual units of analysis (n=1006). Watersheds are increasingly used as integrated ecological units to assess and manage natural capital and ecosystem services (Lant et al. 2005), even though this approach fails to capture larger-scale interactions among watersheds. As delineated in SE Alaska (Albert 2006), most watersheds represent roughly equivalent areas in extent (with some very large outliers). Thirdly, I used habitat area or anadromous stream length as proxies for good/service flows associated with each wildlife or fish species, because region-wide population estimates were not available, except for salmon. For salmon, I used both a habitat proxy (stream length) and a direct measure of salmon productivity that classifies watersheds as primary, secondary, and non-producing (ADFG 1998).

Spatial data for the harvest of fish and wildlife were not available for all user groups in SE Alaska, so I used the best available proxies. First, I estimated hunting use intensity based on Alaska Department of Fish and Game (ADFG) summaries of harvest by game management unit (GMU). Each GMU typically consists of 3-5 watersheds. Harvest data from ADFG was based on game tags associated with hunting permits and hunter surveys, and thus did not include unreported harvests (which are common for rural subsistence users). Most permit holders and survey respondents live in the population centers of Juneau and Ketchikan. Spatially explicit hunting data for the other 32 rural communities of SE Alaska were not available at the time of analysis. As a result, I made the assumption that rural subsistence hunters use the same watersheds in the same proportions as ‘urban’ hunters. There were also several important categories of fish/wildlife use that were not included in the analysis for similar reasons; e.g., other subsistence harvests of fish, seafood, and plant materials. Datasets reflecting non-consumptive guide/outfitter activities such as ecotourism and wildlife viewing were not available in region-wide coverages at the time of analysis. Instead I used recreation sites (e.g., public use cabins and trails) as proxies of these types of use. Lastly, commercial fishing occurs almost entirely in ocean passages and could not be spatially coupled to specific watersheds.

Another major issue I encountered was how to incorporate roads in the analysis. Roads are one of the scarcest 'resources' in SE Alaska, and are thus a critical form of access for a variety of user groups. Much of the road network is composed of former logging roads that are maintained by the US Forest Service to support multiple-use in managed landscapes. Roads and other forms of human land use serve a variety of purposes, thus it unclear how their existence may cumulatively affect the capacity for humans to receive/use ecosystem services in SE Alaska. For some uses, especially those that are the focus of this analysis (e.g., hunting and fishing), roads may be beneficial; while for other uses, such as remote recreation and wilderness preservation, roads may be less desirable. Because of inadequate information on these aspects of roads, I elected not to use roads as an indicator of human use in the assessment of watersheds. In part, the spatial distribution of use data (e.g. hunting and fishing) already reflects the importance of roads (ADFG 1998). Instead I used roads as an indicator of disturbance, focusing on the frequency of stream-road crossings (per watershed), with a separate indicator for salmon stream crossings.

6.5.6 Analytical methods

A criteria-and-indicators approach was used to aggregate multiple GIS coverages in order to calculate watershed criteria scores; the method is described here. Data coverages in the GIS were evaluated as indicators of one of three criteria: 1) ecological capacity to provide/support populations of fish/wildlife (*provision*), 2) human use of fish/wildlife through consumptive and non-consumptive activities (*use*),

3) and man-made disturbance related to timbering and roading (*disturbance*). A complete listing of criteria and indicators is provided in Table 1. First, each indicator was calculated for each watershed based on the value of the GIS data elements. Some indicators were area-weighted (e.g., percent total productive forest harvested); all others were calculated by total area (e.g., productive forest) or length (e.g., salmon streams) within the watershed. Next, to calculate criteria scores for each watershed, I ranked all watersheds in SE Alaska (n = 1006) separately for each indicator. Watersheds could have the same rank for an indicator if the data elements were equivalent (e.g., zero acres harvested forest). These individual rankings were then summed (without weighting) for all indicators of a given criterion for each watershed; to provide an aggregated criterion score for each watershed. Watersheds were then given a rank for each of the three criteria based on these aggregate scores; watersheds could have the same rank for a criterion if the scores were equivalent (e.g., a zero *disturbance* score for totally unmodified watersheds).

The main purpose in constructing criteria and evaluating watersheds was to allow regional-scale comparisons of *provision*, *use*, and *disturbance* across watersheds. To this end, I identified subsets of watersheds of interest and compared these subsets in different ways. I arbitrarily chose two benchmarks to create the subsets of interest: 1) the upper 50th percentile of watersheds by each criterion, which I defined as 'important' watersheds; 2) the upper 20th percentile, which I defined as 'critical' watersheds. Thus 'critical' watersheds were a nested subset of all 'important' watersheds. I amended watershed attributes in the GIS to include the three criteria ranks; subsets were created by querying the GIS using conditional statements.

Two brief applications of the analytical approach are demonstrated in this study. Using intersect operations in the GIS, I created two additional subsets of watersheds: 1) those with upper 50th percentile ranks in both *provision* and *use*, hereafter referred to as 'important *provision-use*' watersheds; and 2) those with upper 20th percentile ranks in all three criteria (*provision*, *use*, *disturbance*), or 'potentially vulnerable' watersheds. First, what is the overall condition, or integrity, of ecosystem services of concern in a region? I use the 'important' subset (upper 50%) of *provision*, *use*, and *provision-use* watersheds to evaluate the intensity of man-made disturbance in those areas, to estimate the overall integrity of fish/wildlife ecosystem services at the landscape scale. Second, what areas of critical flows are possibly vulnerable? I identify the 'potentially vulnerable' watersheds to focus on the locales where resilience may currently appear high, but where vulnerability may emerge for several reasons.

6.6 Results

The *provision* ranks were uniformly distributed among watersheds, meaning that nearly every watershed had a unique rank (from 1-1006). Based on available data, nearly half of the watersheds had no recorded human use or disturbance; i.e., 418 watersheds (comprising 40.3% of the region) shared the lowest *use* rank. This highly skewed distribution reflects the smaller number of indicators in the *use* criterion, due to data limitations. 487 watersheds (49.5% of the region) shared the lowest *disturbance* rank, which reflects both the paucity of indicators and the largely pristine state of the SE Alaska landscape.

6.6.1 Overall integrity of fish/wildlife services

At the regional scale, a baseline measure of ecological resilience is the proportion of productive areas that have not been directly modified by human disturbance. The relative intensity of human disturbance in these 'important' watersheds for SE Alaska is shown in Figure 6.2. These results show the percentage of important areas that have been 'modified' (e.g., any degree of man-made disturbance greater than zero) and 'highly modified' (e.g., watersheds with a disturbance rank in the upper 20th percentile); thus by my definition, 'highly modified' watersheds are a nested subset of all 'modified' watersheds. Of the important *provision* watersheds, roughly four out of five (81%) have not been highly modified by timber management, roads, or urban land use, while nearly one-half (45%) have not experienced any of these direct disturbances (Figure 6.2). The intersection of important *provision* and important *use* watersheds provided a subset of 311 watersheds, approximately 33% of the regional area, where the production and harvest of fish/wildlife resources have been spatially coupled. Approximately 70% of these watersheds have not been highly modified by disturbances related to timber or urban land use. Overall, these results suggest a moderate to high integrity of ecosystem services related to fish/wildlife in SE Alaska.

6.6.2 Potentially vulnerable watersheds

Maps depicting critical *provision*, *use*, and *disturbance* watersheds in SE Alaska are provided in Figure 6.3. These subsets were intersected using a GIS query to identify those with all three criteria ranks in the upper 20th percentiles. I found 26 watersheds, comprising approximately 2.5% of the regional area, that have high ecological capacity for fish and wildlife provision, high human use intensity, and high anthropogenic disturbance (Figure 6.4). These primarily occur in areas historically associated with timber extraction (n=24), with the remainder influenced by urban land use (n=2). Nearly all of these watersheds are important for hunting, and over half have been designated primary sport-fishing areas by ADFG. Because these watersheds are critical for provision and use of ecosystem goods and services in SE Alaska, they indicate the tight coupling of social and ecological processes, where the impacts of man-made disturbance may result in degradation of ecosystem service flows at local scales.

6.6.3 Impact of federal land use policy

For these regionally important watersheds, I calculated the percentage of total area in protected (legislative or administrative) and unprotected categories of land status. Each of these land use groupings comprises roughly one-third of the region (by area). Figure 6.5 shows the proportion of area in each subset (provision, receipt and coupled provision-receipt) protected by legislative measures. Legislative protections provided by Wilderness, National Monuments and National Parks currently prohibit nearly all forms of direct modification in roughly one-third of these important areas. Overall, nearly 60% of these areas are protected in some way, when the administrative protections afforded by the 'natural setting' land use designations of the 1997 Tongass Land Management Plan (TLMP) are included. The remaining area (roughly 40%) has either already been modified (e.g. timber harvest and roads), is scheduled for timber harvest by the 1997 TLMP, or is held by various non-federal landowners that retain development rights (e.g. Alaska Native corporations, state and local governments, and private individuals). Nearly 90% of Native-owned lands have been managed for timber production.

6.7 Discussion

There are several potential ways to interpret these results depending on the scale of interest, keeping in mind the multiple caveats and limitations of the analysis (see methods). At the regional scale, a simple baseline measure of resilience is the proportion of important areas that have not been directly modified by human disturbance. I found that this proportion of important areas (for provision, receipt and coupled provision-receipt) ranges from 35-45%; and the proportion of important areas not 'highly modified' was between 73-81% (Figure 6.2). These results also suggest that overall, important provision areas are less modified than important receipt and coupled provision-receipt areas. This finding was expected for two reasons: first, as an artifact of the analysis because roads were evaluated in the *disturbance* criterion and not included in the USE criterion, to avoid double counting; and second, because roads and resource use intensity are spatially correlated in SE Alaska (ADFG 1998). Roads and other forms of human land use serve a variety of purposes, thus it unclear how their existence may cumulatively affect the resilience of human receipt of ecosystem services in SE Alaska. For some uses, especially those best described by this analysis (e.g., hunting and fishing), roads may be beneficial; while for other uses, such as remote recreation and wilderness preservation, roads may be less desirable. Likewise, other disturbances such as timber harvesting and urban land use may facilitate certain uses and discourage others.

At the regional scale, we can also observe the degree to which SE Alaska land conservation policy contributes to resilience by supporting the integrity of ecosystems that provide goods and services. Depending on the level of protection, between 32% (legislative only) and 60% (legislative and administrative) of regionally important provision/receipt areas are managed to maintain a relatively unmodified condition (Figure 6.5). In particular, the legislative protections created by ANILCA, TTRA and Glacier Bay National Park afford a stable source of resilience, because any changes to the governance of these lands will involve all three branches of the federal government; e.g. legislated by Congress, approved and implemented by the executive, and subjected to federal jurisprudence (in all likelihood). The Forest planning process, although subjected to the influence of Congress (via the budgeting process) and federal courts (via litigation), is largely driven by Tongass-USFS managers and upper-level officials in the executive branch. Since the land use designations (LUDs) of the Forest Plan are revisited every five years and revised every twenty years, the administrative protections of Tongass LUDs are probably more 'fluid' than legislative protections. In other words, it is more likely that Tongass LUDs will change before any major reforms to federal land use policy occur in SE Alaska.

At the watershed scale, my analysis provided a proxy measure of historical resilience in response to man-made disturbance in SE Alaska. If a watershed can be considered resilient to its human disturbance when it maintains the capacity to support provision and receipt of the same (or mostly similar) bundle of goods and services, then a vulnerable watershed is one where this capacity has been depleted or transformed (into a new bundle of goods and services). Of course, the lack of a temporal component in the available data does not allow the explicit description of watershed-scale resilience over time. Instead, the snapshot approach described these watersheds only as they currently exist; meaning that any causal inferences must be based on the premise that historical disturbances have impacted modern patterns of provision/receipt. In other words, we must assume that low provision/receipt is an emergent outcome of human disturbance. Given this premise, I found that among the current areas of lesser importance (e.g., those ranked in the lower 50%) in coupled provision-receipt, 36.0% was modified and only 11.6% was highly modified. This suggests that there is a small proportion of the SE Alaska landscape that may have previously been important for provision-receipt, but has lost that capacity due to intensive modification. Thus it appears that provision/receipt of ecosystem services in SE Alaska has been resilient to human disturbance regimes, to the present day.

A final way to interpret these findings involves looking forward instead of backward in time. To this end, I evaluated resilience and vulnerability based on those areas with high degrees of disturbance that remain important loci for ecosystem services. I identified these places as potential vulnerabilities in the SE Alaska SES (Figure 6.4), although in a sense, these areas *currently* appear to be highly resilient. However, it is expected that forest regeneration and road closures, as emergent processes arising from logging disturbance, will negatively impact provision/use over the long term.

As second-growth forests regenerate into the stem exclusion stage, habitat quality is expected to be reduced for wildlife species important for subsistence and commercial use. The second-growth condition - which is thought to be very low quality habitat for most endemic mammals, including game species like deer and bear - is expected to persist for between 50-150 years, depending on site productivity and a number of other factors (Hanley et al. 2005; Shaw et al. 1999).

Forest roads, especially those constructed for logging purposes, continue to require regular maintenance and management attention. Because of steep, rugged terrain and a very wet climate, stream culverts and fish passages in SE Alaska commonly need repair or replacement every 5-10 years. Failure of these structures may result in degradation of aquatic habitats and the integrity of watershed-level hydrological processes. Moreover, concerns over maintenance costs (in part) have prompted recent proposals by the US Forest Service to decommission logging roads in several locales. One of these places, Prince of Wales Island, where nearly half of existing logging roads have been cited for possible closure, supports a rapidly growing sport-hunting and guiding industry. Perhaps more importantly, Prince of Wales Island deer populations are a critical subsistence resource for communities both on and off the island. Road closures may constrain access for both subsistence and commercial users who have become accustomed to roads over the last several decades. Overall, impacts of aging culverts and road closures, as well as longer term forest regeneration processes, are not well understood, as they have no precedent in SE Alaska. Because of this uncertainty, long-term impacts of forest regeneration and road management should be a focus of research to understand and mitigate emergent vulnerabilities.

6.8 Synthesis and conclusions

During the 20th century, Southeast Alaska has seen dramatic changes in management and economy, and is beginning to see a range of impacts of ecological change related to climate and forest management. While it has undergone transition in recent years, the social-ecological system of SE Alaska appears to have retained many of the critical interactions that link human and natural communities. For this reason, this research suggests that SE Alaska has been a resilient social-ecological system. Despite the apparent vulnerability of local ecosystems to climate change and the collapse of its primary land management regime, the SE Alaska SES has heretofore exhibited the capacity to reorganize while retaining many of its defining characteristics. Southeast Alaskans remain closely tied to their natural landscape in critical ways, such as subsistence and commercial uses of fish/wildlife resources. My findings suggest that retention of social capital (e.g., knowledge of local ecosystems and their resources) and natural capital (e.g. the capacity of ecosystems to produce resources) has afforded resilience in the ongoing economic transition. The initial analysis of ecosystem service provision and use (in this chapter) suggests a relatively high degree of integrity of these interactions. However, the alarming rate of forest decline related to climate change and the future implications of four decades of production forestry in SE Alaska are causes for concern. Impacts of climate change on subsistence are uncertain, but are likely to be wide-ranging and significant. With respect to the long-term impacts of timber management on the provision and use of fish/wildlife resources, areas of emergent vulnerability are apparent. During the reorganization phase of federal management, it is crucial to address both the uncertainties related to climate change and the emergent vulnerabilities in the provision and use of key ecosystem goods/services.

Across the state space of a system, which represents the total possible combinations of interacting variables that define the system, stability domains or "basins" may emerge. When a system enters a stability domain, a considerable amount of effort must be applied to move the system into a different domain. In this sense, the system is highly resilient in its current state. Although resilient, systems may be in undesirable states (Holling et al. 2002; Walker et al. 2004; Carpenter and Brock 2004). This is the case for federal management system in SE Alaska, as my findings suggest. The management system appears to be 'trapped' in a stability domain, with undesirable outcomes resulting from the economic and political legacy of the industrial forestry regime of the past. These include the highly contentious and mistrustful atmosphere surrounding Tongass decision-making and resource planning, and the senescent condition of much of regional mill infrastructure, which operates well below capacity despite the availability of timber and improving market conditions. Both outcomes reflect that the economic and policy subsystems - that have historically shaped the larger management system - are mired in undesirable stable states. Overall, it seems that the reorganization of federal land management in

SE Alaska cannot proceed until these systems ‘escape’ these stability domains and transition into different states.

As discussed in Chapter 5, moving the state of federal land management in SE Alaska away from the stability domain in which it is currently and undesirably ‘trapped’ will require effort in several areas. First and foremost, the USFS-Tongass must continue to foster stakeholder participation in the early stages of the planning process. Further measures should be taken to increase the level of cooperation and trust among stakeholders, environmental groups, industry, and Tongass managers, with the goal of reducing the heavy burden of litigation and appeals. A wholly different means to this end - an attempt by the current administration to strictly limit the capacity for stakeholders to appeal and litigate Forest Service decisions - is counterproductive, because it mainly serves to foster greater mistrust among parties (Nie 2006). Numerous federal policies assure the rights of these interests, including ‘outside’ environmental groups, to influence the decision-making process. These policies, as I have frequently noted, have been the principal drivers of change in federal management of SE Alaska. It appears that the ‘critical mass’ of environmental policy has reshaped the state space of the SE Alaska management system, creating the current ‘basin’ of attraction in which the system exists. Without compromise and reconciliation, the management system will either remain in the current “quagmire” or transform into a different and unstable configuration; e.g., remobilization of industrial forestry, or to the other extreme, the prohibition of timber harvesting. Neither regime would likely be stable over the long term, given the vulnerabilities of each to the internal and external drivers of change that have shaped the current outcomes in SE Alaska. Instead, as I suggested in Chapter 5, a reorganization of management priorities that seeks the cooperation of a range of stakeholder interests - thus easing the current controversy - is needed to transition towards a more sustainable future.

To this end, a second focus of reorganization should be the region's increasing economic dependence on non-consumptive activities (e.g., many forms of recreation) and non-market amenities (e.g., scenery, wilderness character, isolation). Historical land use patterns will almost certainly impact these ecosystem services, thus affecting the future quality and quantity of their associated benefits. Fortunately, as my analysis of ecosystem services in SE Alaska suggests, it appears that a relatively small and manageable proportion of the landscape may be immediately vulnerable, with respect to the provision and use of ecological goods and services. (Of course, much better information is needed to evaluate the status of SE Alaska ecosystem services in a manner that will be useful for management.) In short, I propose that the Forest Service needs to broadly expand the concept of 'multiple-use' management, and in turn, reorganize its implementation at both local and regional scales. To this end, the agency should consider a totality of resources, ecosystem services, and non-market values, many of which have been heretofore ignored in the planning and decision-making process. A considerable research effort is needed to address these information deficits using both scientific and local/traditional knowledge.

Managers and landowners must also learn to account for climate change and its associated social-ecological uncertainties in developing their land use plans. In particular, the management of second-growth forests in a changing climate and shifting economy will present both challenges and opportunities. The continued implementation of adaptive management principles by the Forest Service is essential to observing the emergent and unpredictable changes that are almost certain to come, as multiple drivers of local and global of change converge in the social-ecological system of SE Alaska. By fostering a flexible and sustainable stewardship of second-growth forests in a balanced proportion of their myriad uses and services, the Forest Service may safeguard SE Alaska from experiencing yet another boom-bust cycle, like those of gold and timber in decades past.

Table 6.1. Criteria, indicators, and data sources used in the Southeast Alaska social-ecological GIS.

Criteria	Indicator	Data	Format	Source
PROVISION	High productivity upland forest [1]	TIMTYPE	Grid	USDA, TNC
	High productivity riparian forest [1]	"	"	USDA, TNC
	Productive upland forest	"	"	USDA, TNC
	Productive riparian forest	"	"	USDA, TNC
	Bear habitat [2]	HSI model	"	USDA
	Deer habitat [2]	"	"	USDA
	Marbled murrelet habitat [2]	"	"	USDA
	Bald eagle habitat	Nests	Point	USDA
	Migratory waterfowl	Primary sites	Polygon	ADF&G, TNC
	Salmon streams	AWC	Line	FWS
	Salmon production [3]	TRA model	Watershed attribute	ADF&G
	Berries (e.g., *Vaccinium* spp.)	PLANTCOMM	Grid	USDA
USE	Sport-fishing [4]	TRA model	Watershed attribute	ADF&G
	Deer harvest	Harvest Tags (GMU)	"	ADF&G
	Black bear harvest	"	"	ADF&G
	Brown bear harvest	"	"	ADF&G
	Recreation sites	Cabins, trails	Point and line	USDA
	Shellfish	Major harvest sites	Polygon	ADF&G, TNC
	Aquaculture	Site location	Point	USDA
DISTURBANCE	Harvested productive forest [5]	TIMTYPE, LANDCOV	Grid	USDA, TNC
	Urban land use	LANDCOV	Grid	TNC
	Roads and streams [6]	Roads, LANDCOV	Line	USDA
	Roads and salmon streams [6]	Roads, AWC	Line	USDA, FWS

Key to acronyms:

TIMTYPE: forest condition (species, volume, age class); HSI model: habitat suitability index (based on several habitat-related variables); AWC: anadromous waters catalog (streams with salmonid species); TRA model: Tongass resource assessment (identified major salmon producing and sportfishing areas in SE Alaska); LANDCOV: landcover grid (13 cover types); PLANTCOMM: plant communities (including understory shrubs); GMU: game management units; USDA: US Department of Agriculture Forest Service; ADF&G: Alaska Department of Fish and Game; TNC: Dave Albert, The Nature Conservancy (Juneau, AK); FWS - US Fish and Wildlife Service

[1] High productivity forests were counted separately from the remainder of (less) productive forest types

[2] Land area in upper 50th percentile habitat suitability, based on model evaluation

[3] Primary and secondary salmon producing watersheds as identified by the Alaska Dept of Fish and Game

[4] Primary sport-fishing areas as identified by the Alaska Dept of Fish and Game

[5] Percent of productive forest in watershed that has been harvested

[6] GIS coverage created for this study; estimates number of road-stream crossings per watershed

Figure 6.1. Conceptual model of social-ecological interactions.

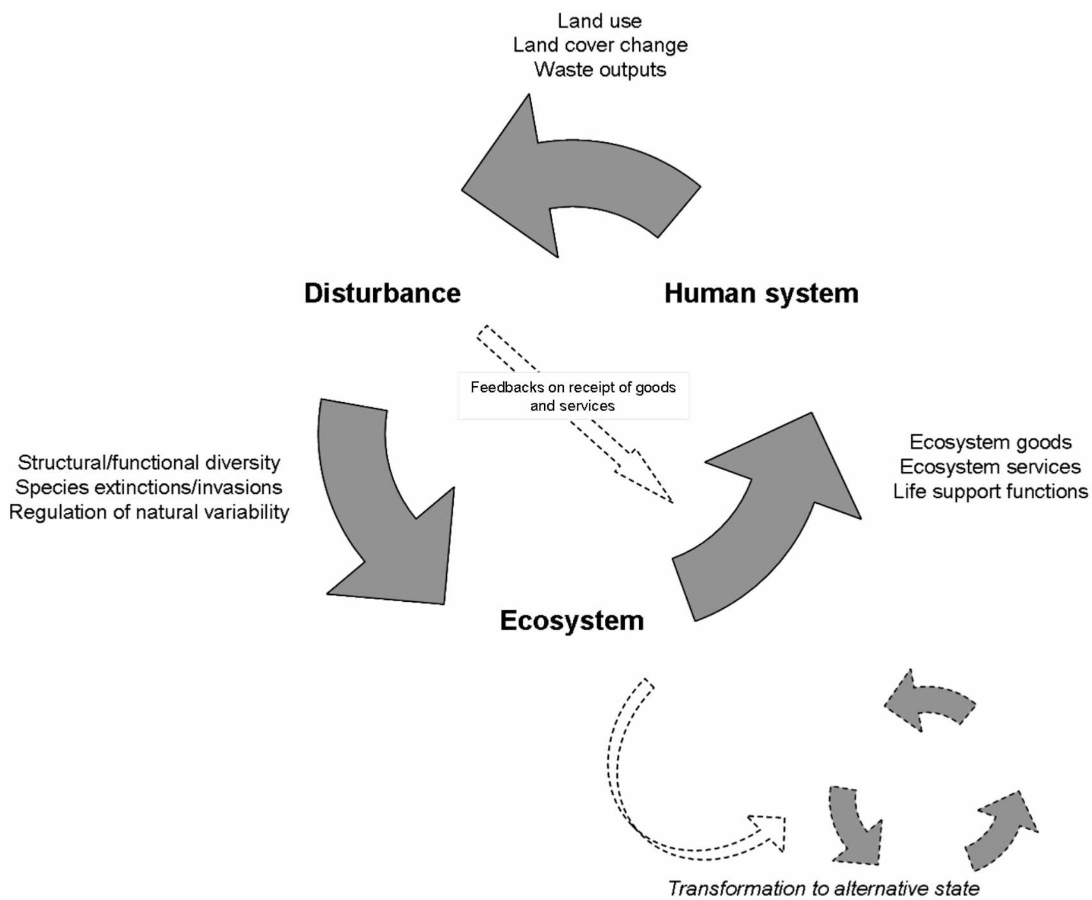


Figure 6.2. Disturbance intensity in regionally important watersheds for the ecological provision and human use of fish/wildlife resources in Southeast Alaska. Below are those watersheds ranked in the upper 50^{th} percentile of all watersheds (n=1006) for *provision* and *use* criteria, and those with upper 50^{th} percentile ranks for both criteria (*provision-use*). Estimates of disturbance intensity are based on evaluation of the DISTURBANCE criterion for each watershed. The categories 'modified' and 'highly modified' are defined in the methods section of the text. Criteria, indicators and data are described in Table 6.1.

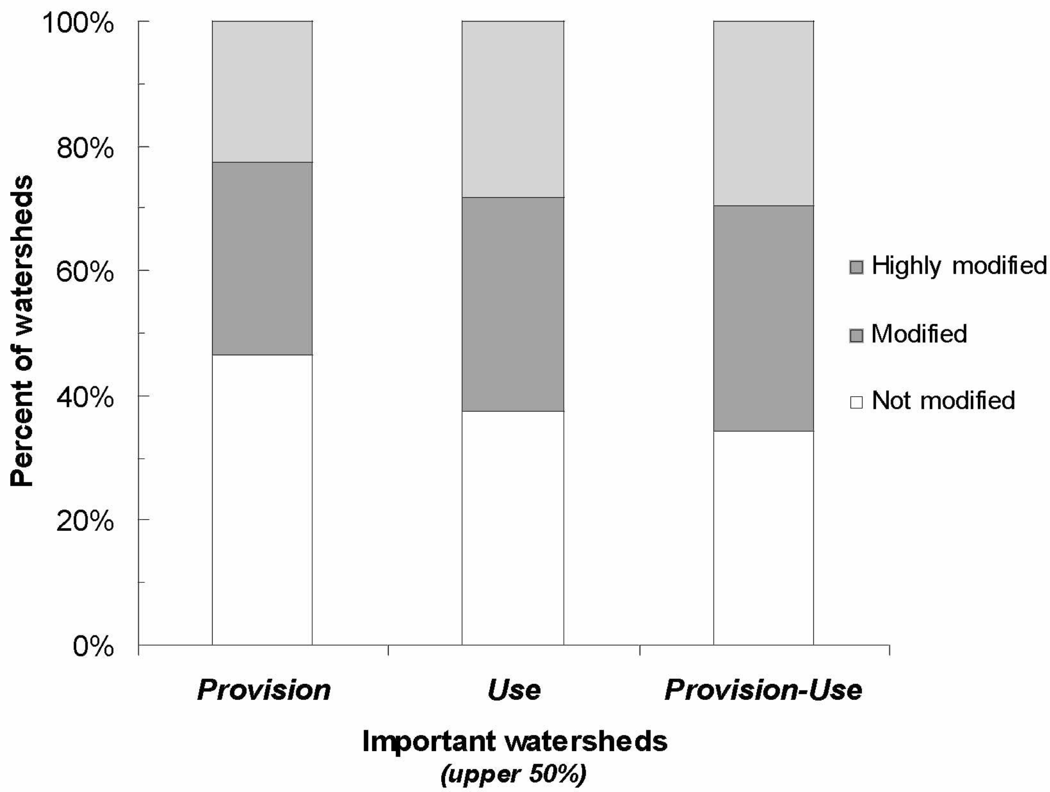


Figure 6.3. Maps of critical watersheds as evaluated by the provision, use, and disturbance criteria for Southeast Alaska. Watersheds depicted in dark grey are ranked in the upper 20th percentile for each distribution of criteria scores. Criteria, indicators and data are described in Table 6.1.

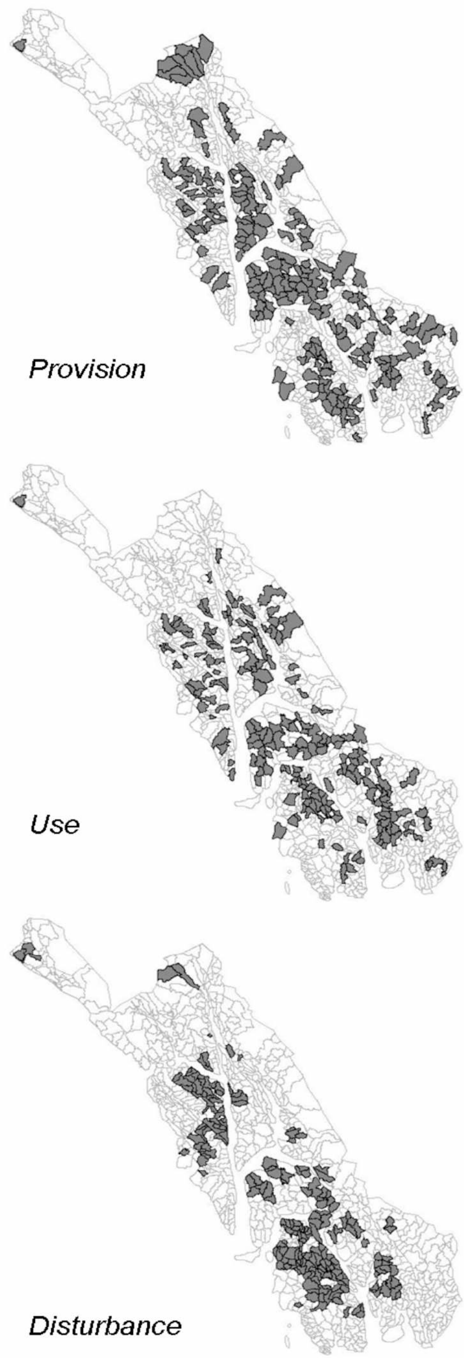
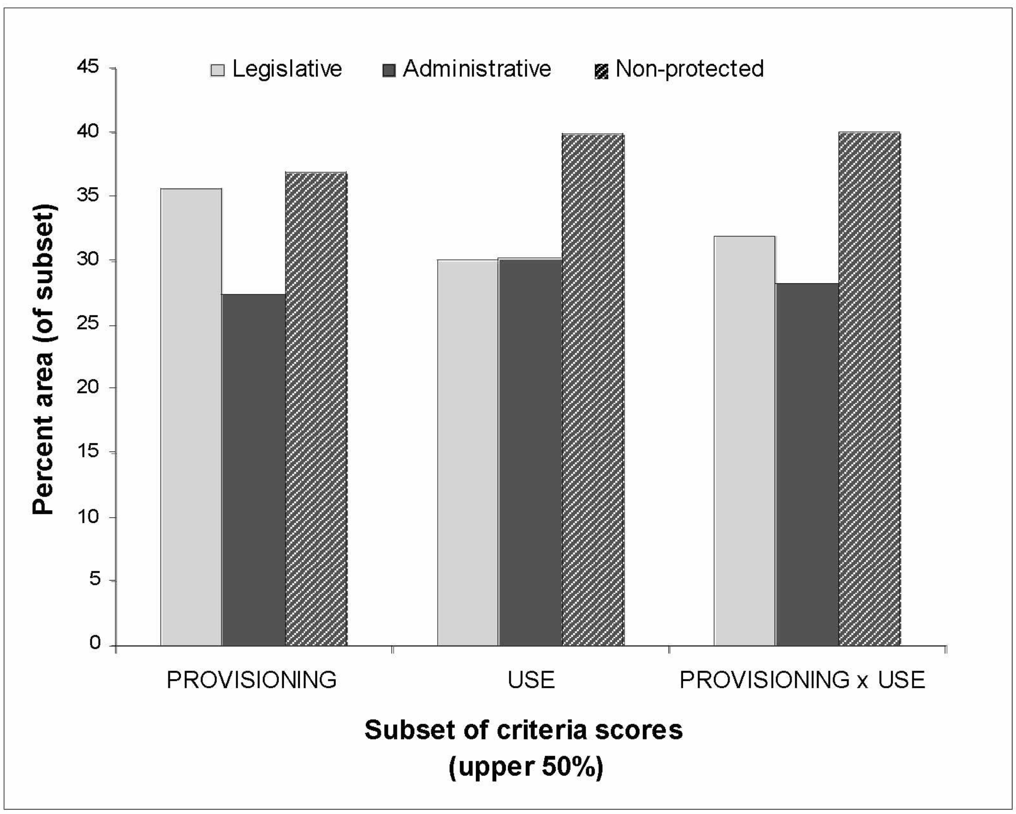


Figure 6.4. Potential locales of emergent vulnerability in fish and wildlife ecosystem services in Southeast Alaska. Watersheds depicted in black have high provision of fish/wildlife, high human use of fish/wildlife, and high human disturbance related to timber management; e.g. each watershed has all three criteria ranks in the upper 20th percentile (or 'critical' watersheds).

Figure 6.5. Land protection status of regionally important watersheds for the provision, receipt and coupled provision-receipt functions of ecosystem goods/services in SE Alaska. Criteria, indicators and data are described in Table 1. Legislative protections include Wilderness, National Monument and Parks created by Congress, where nearly all development activities are prohibited (39.2% of the SE Alaska region). Administrative protections include the ‘natural setting’ lands of the Tongass National Forest, where some development and land use is permitted, but intensive development is not allowed (28.2% of the region). Non-protected lands include Tongass ‘intensive development’ areas and all non-Tongass lands (32.5%).



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